ELEMENTARY COURSE

OF

BOTANY

STRUCTURAL, PHYSIOLOGICAL

AND

SYSTEMATIC.

BY

PROFESSOR ARTHUR HENFREY, F.R.S., L.S., ETC.

THIRD EDITION.

BY

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EXAMINER IN BOTANY TO THE UNIVERSITY OF LONDON.

ILLUSTRATED BY UPWARDS OF SIX HUNDRED WOODCUTS.

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ALERE FLAMMAM.

PREFACE TO THE THIRD EDITION.

In the preparation of this edition so much has been added, and so much modified, that to some extent the book may be considered as a new one. Nevertheless, the Editor has, as far as possible, worked on the plan laid down by Prof. Henfrey, and explained by him in the following quotation from the original Preface. Adverting to some remarks made by Sir Joseph Hooker and Dr. Thomson to the effect that

"disservice is done to the cause of Botany by occupying the attention of students in the first instance with the abstract parts of the science,"

Prof. Henfrey remarks, in terms as applicable now as at the time they were first written (1857), that

"The largest class of students of Botany are those who pursue the subject as one included in the prescribed course of medical education. One short course of Lectures is devoted to this science, and three months is commonly all the time allotted to the teacher for laying the foundations and building the superstructure of a knowledge of Botany in the minds of his pupils, very few of whom come prepared even with the most rudimentary acquaintance with the science. To direct the attention of the student to a series of isolated facts and abstract propositions relating to the elementary anatomy of plants, is to cause him to charge his memory or his note-book with materials in which he can take but little interest, from his incapacity to perceive their value or applications. Some of the most important questions of Physiology are as yet in no very advanced state, and the conflicting evidence on many of these cannot be properly appreciated without an extensive knowledge of plants.

"But if we endeavour to seize the floating conceptions furnished by common experience, and to fix and define them by a course of exact practical observation of the more accessible characters of plants (showing the relations of these as they occur in different divisions of the Vegetable Kingdom), we place the student in a position which enables him to proceed at once with an inquiry into the peculiarities of the plants he meets with, and in this way to acquire a fund of practical knowledge, which is not only absolutely requisite before entering on abstract inquiries, but is especially calculated to secure his permanent interest in the study.

"Physiology is undoubtedly of the highest importance, and from its nature is that part of the Science which, were it not for the above difficulties, would with most advantage be taught by Lectures. If the previous education of medical students prepared them, as it should, with an elementary knowledge of the Natural Sciences, we should make Physiology the most conspicuous feature of a course of Botany in a Medical School. In the mean time we subordinate it to the other branches in practical teaching, and in this volume have dealt with it in what we regard as its proper place in the order of study."

Since these remarks were written, and owing in part to the advances made in the Science of Vegetable Physiology, the subject has received more attention in this country, while at the University Examinations greater stress than heretofore is laid upon it. However desirable in one sense this may be, it is at present objectionable, because few or no means are open to the average student of making himself practically familiar with Experimental Physiology. Moreover, the skill in manipulation and microscopical observation required for anatomical or physiological investigations cannot possibly be acquired in the few months devoted to the subject by the majority of students and candidates for examination in the Scientific and Medical Faculties. Sooner or later these defects in the practical teaching of Physiology will doubtless be remedied. In the mean time, practical tuition in Morphology and the rudiments of Classification appears to be the best and most ready method of training a student to observe, to reflect, and to classify.

By its means also the evil effects of the system of loading the memory with secondhand information—of no use whatever outside the walls of the examination-room, and indeed of but little service in the practical examinations (now happily instituted at the University of London and elsewhere)—may be avoided.

In the present edition the additions to the Morphological chapters have been chiefly taken from the writings of Braun, Baillon, Eichler, Warming, Van Tieghem, and others. In this department the Editor has also to acknowledge the valuable assistance rendered him by the Rev. George Henslow, particularly in the sections relating to phyllotaxis and æstivation.

In the arrangement of the Natural Orders the plan adopted by Bentham and Hooker in their invaluable 'Genera Plantarum' has been followed so far as that work extends.

The account of the Cryptogamia has been revised, and that concerning the Fungi written afresh by Mr. George Murray, of the Botanical Department of the British Museum, to whom the Editor would here offer his cordial acknowledgments.

The Physiological Section has been mostly rewritten, and much has been added to it. Use has been made of Sachs' 'Handbuch der Experimental Physiologie der Pflanzen'; of the English and French translations of the 'Lehrbuch,' of the same author—the former published under the superintendence of Messrs. Bennett and Thiselton Dyer, the latter under that of M. Van Tieghem, whose version is enriched with numerous original notes. In addition, the Editor has availed himself of Duchartre's 'Éléments de Botanique,' Dehérain's 'Cours de Chimie Agricole,' and more especially of numerous recent original memoirs published by Boussingault, Darwin, Trécul, Pfeffer, Janczewski, Corenwinder, Van

Tieghem, Strasburger, Lawes and Gilbert, McNab, Vesque, Rauwenhoff, Warming, and many others whom it is not possible to specify in a work of this character.

Comparatively few alterations have been made to the chapters on Geographical and Geological Botany, which, for their effective treatment, would require another volume. The additions in these subjects have been chiefly derived from the writings of Hooker, Grisebach, Tchihatchef, Williamson, Crépin, and Carruthers.

Some additional woodcuts have been supplied, whose source is acknowledged in the text.

M. T. M.

March 1878.

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AN
ELEMENTARY COURSE
OF
BOTANY.

GENERAL INTRODUCTION.

Sect. 1. OBJECTS AND SUBDIVISIONS OF THE SCIENCE.

BOTANY is that department of Natural Science which deals with Plants, their conformation, life-history, relations one to another and to the universe of which they form a part. No absolute distinction can be drawn between plants and animals.

At the outset we must be content with the conception of a plant as furnished by the previous experience of the student; this will be enlarged and at the same time rendered clearer by the study of the following pages; and, after the more important principles of physiology have been expounded, a clearer notion of the relation of plants to other living beings as well as to unorganized or mineral substances may be obtained.

Botany is divisible into two principal departments:—the *Natural History of Plants*, which deals with the characteristic phenomena presented by the individual kinds of plants; and *Philosophical Botany*, the object of which is to ascertain the general facts and laws which pertain to more or less considerable assemblages of plants.

Philosophical Botany represents the pure science; and it is with the departments of this we have chiefly to do in this work. The Natural History of Plants, which in early times constituted the whole science, resolves itself, at the present time, into a number of distinct branches of *Applied* or *Practical Botany*.

Philosophical Botany includes the following departments:—

I. *Morphology*, or the *Comparative Anatomy* of plants, consisting of the study of the outward forms of the diverse parts of plants.

II. *Elementary* or *Philosophical Anatomy*: the study of the tissues of which plants are composed, and the intimate structure of their several parts.

With these two is conveniently associated the *Terminology*, or technical language of Botany.

III. *Physiology*: the study of vital phenomena, or of those processes and actions performed by the living plant, including those specially characteristic of plants, and also those which are common to the animal kingdom, as well as the consideration of the general physical agencies pertaining to the mineral kingdom equally with the two others.

IV. *Classification*, which is the study of the mode of arranging the kinds of plants in groups and series of groups either "artificially," when convenience and facility of study are the chief aims, or according to their supposed lineage and kinship, and thus to express in an abstract form their mutual relations and their degrees of perfection in organization. This department includes the *Principles* of *Descriptive Botany* and of the *Nomenclature* of kinds and classes of plants.

Applied Botany is divisible into many departments. That most closely connected with Philosophical Botany is *Descriptive Botany*, which is the art of describing the particular kinds of plants in technical language, in such a manner that they may be readily recognized by botanists. Special works are commonly devoted to this branch, and are very commonly confined to the plants of a limited area, as a particular country or even province; such books are called *Floras*. *Pharmaceutical Botany* treats of the medicinal, nutritious, or poisonous properties of plants. Vegetables possessing such properties are generally included under the head of *Materia Medica*, to which subject special treatises are also devoted. *Agricultural*, *Horticultural*, and *Economic Botany* are often treated as distinct subjects: the first two are founded on the application of the principles of Physiological Botany; the last on the ascertained facts of Comparative and Elementary Anatomy, and on the combination of these facts with chemical and mechanical knowledge.

None of these departments of Applied Botany receive separate treatment in this work, although incidental reference is made to them to indicate the application of the laws and facts of Philosophical Botany to them.

Botanical Geography and *Botanical Geology* (or *Palæontology*) are mixed studies, founded on the association of the results of pure and of applied Botany with those of other sciences: the first is related most closely to Physiological Botany, but has some problems *sui generis*, to be solved only by independent facts and observations; the second has some very interesting relations with the Scientific Classification of plants. These two departments, as applications of the science, have a peculiar philosophical interest, but can only be very briefly alluded to in this volume.

In the present work, the different departments are treated of in the following order:—

Part 1. Morphology, or Comparative Anatomy of Plants. 2. Systematic Botany. 3. Physiology, including Physiological Anatomy. 4. Geographical and Geological Botany.

Sect. 2. METHODS AND MEANS USED IN THE STUDY OF BOTANY.

Examination of Plants.—The study of the morphology of plants, to which the first Part of this volume is devoted, necessitates little more than a supply of fresh specimens, a penknife, two or more needles mounted in handles, and a pocket magnifying-glass of moderate power. One of the needles should be of the ordinary form, and others with a flat top with a cutting-edge like a hare-lip pin. Roots, stems, and leaves require little or no preparation; and the dissection of most flowers is a very simple operation. The majority of the characters of many flowers may be observed by simply removing successively the parts with a penknife, and by examining them in perpendicular and cross slices. In any case care should be taken to detach and observe the parts in regular order, so as to ensure an accurate knowledge of the way in which the different parts are arranged. Perpendicular sections of entire flowers made through the centre and from below upwards are very instructive; and horizontal sections through unopened buds, both of leaves and flowers, are likewise necessary for the examination of the relative position of the organs and of the way in which they are packed. When flowers are extremely minute, and also for the investigation of the structure of ovules and seeds, a pocket-lens mounted on an upright bar, or a *simple microscope*, becomes requisite. The latter instrument consists essentially of a stand, provided with a movable arm supporting a magnifying-glass over a stage upon which the object is laid, so that both hands may be at liberty for its dissection. The stage is an open frame, upon which a slip of glass rests; and the object to be examined, lying on the glass slip, may be illuminated by a small mirror beneath sending light *through* it, or, if required, by a condensing-lens at the side bringing a bright spot of converging rays *upon* it. The dissection is effected with a fine dissecting scalpel and needles. By their means the parts of the flower can be separated one from another so as to show their numbers, form, combination, and position with regard one to another.

In pursuing the study of Systematic Botany, the same means are used, the only difference being that the investigation of each

To those who follow out Systematic Botany in detail, and wish to gain acquaintance with the species of plants, it becomes necessary to have access to a *Herbarium*—that is, a collection of plants so dried that the specific characters, at least, are preserved. In many cases, if the drying has been carefully effected, the generic characters may be ascertained by soaking the flowers in boiling water, when they become softened and the parts separable, like tea-leaves after infusion. Herbaria furnish materials for the comparison of plants, as it is seldom that a number of species of one genus can be obtained either wild or in gardens in a fresh state at one time. Persons living in the country, and studying the British plants, will find it indispensable to form a collection of dried specimens.

devoured by insects of various kinds*. Plants preserved in herbaria, especially if rare or local species, should always have the time and place where they have been gathered carefully noted.

Anatomical Study.—The study of the Elementary Anatomy and the Physiology of Plants opens up a far more extensive field for the employment of instruments and technical manipulations. First of all a *compound microscope* is an essential. For the student, magnifying-powers of 1-inch, ½-inch, and ¼-inch are amply sufficient, although the more abstruse questions require the most perfect and powerful instruments that can be obtained. For general students' use the binocular microscope has no advantage over the ordinary instrument.

The tissues of plants are observed for the most part by means of extremely thin slices passing in various directions through the structures. These are usually best made with a razor. Stems, pieces of wood, and other firm objects, when being cut, may be held in the finger and thumb of the left hand; delicate and thin structures, like leaves &c., should be placed between the two halves of a split cork, or rolled round the edge of a cork, and the cork supported by sticking it in the neck of a vial or test-tube, which serves as a handle. Seeds and similar small objects may be fixed, for slicing, on a piece of white wax. Where it is not imperative to examine the tissues *in situ*, small portions may be softened by boiling in water.

Sometimes it is useful to obtain preparations by macerating the softer tissues, either in water or weak acids. In the case of woody structures recourse may be had to an operation which requires a little care: a fragment of the wood should be placed in a watch-glass with a morsel of potassic chlorate, to which a drop or two of nitric acid is added by means of a glass rod, the whole being gently heated for a minute or two, and water being poured on to prevent complete solution. The fragments macerated in any of these ways being placed on a slip of glass beneath the simple microscope, the elementary organs may be picked out with a needle or extremely fine camel-hair pencil, under a simple lens of ½- or ¼-inch focus, and removed to a clean slide.

The thin slices, or the fragments of macerated tissues, should be laid upon a slip of glass, a drop of water added, and a thin glass cover laid on. They may then be examined under the compound microscope. Objects of microscopic dimensions, such as minute Algæ, Fungi, pollen-grains, &c., require no preparation.

* The mixture in use at the Kew herbarium consists of corrosive sublimate one ounce, carbolic acid one ounce, methylated spirit two pints; mix. It must be used with great care, owing to its poisonous qualities.

To render tissues transparent they may be soaked in a dilute solution of caustic potash for a few minutes. If by this means made too transparent, the tissue should be immersed in a dilute solution of alum or of hydrochloric acid.

It is very instructive to apply chemical reagents of various kinds to the objects lying in water upon the microscopic slide. Dilute sulphuric acid is often useful to coagulate protoplasmic structures and to clear delicate tissues; when this is added first, and afterwards solution of iodine, the younger cellular structures turn blue, while the older ones become deep yellow. Iodine alone colours starch-grains blue. Sugar and nitric acid colour the protoplasmic structures red. These reagents may be applied by means of dropping from a glass rod or fine tube. It is often advantageous to soak the sections for some hours in a solution of pure carmine in ammonia diluted with water. The nuclei and cell-contents become tinged with the carmine, and can thus be more readily distinguished from the cell-wall. More particular reference will be made to them in the chapters on Anatomy. Microscopic preparations of soft vegetable structures are best preserved in glycerine or strong solution of calcium chloride. Some objects are advantageously mounted in Canada balsam; these must be well dried first, and, for a few days previously to mounting, should be soaked in spirits of turpentine. Those who desire to obtain minute instructions on the manipulations necessary for the study of Vegetable Anatomy, may consult Schacht's 'Microscope,' translated by Currey, or the articles on these subjects in the 'Micrographic Dictionary.'

In physiological investigation various pieces of philosophical apparatus are requisite. It is also often necessary in studying the life-history of plants, especially the lower ones, to grow them under different conditions and to watch them in their several stages. For these purposes special appliances and chemical solutions are needed.

Lastly the student must remember that Botany is not an "exact" science. Rarely, if ever, can a definition be framed in any branch of natural history which is not subject to frequent and considerable exception. These exceptions arise from the natural variations which occur in all living organisms, either in accordance with existing circumstances or as hereditary tendencies. Again, it must be borne in mind that Botany is a progressive science, and therefore that the language and terminology in general use is not always strictly accurate according to the most advanced state of science; hence many of the terms have to be taken in an arbitrary or in a conventional sense.

PART I.

MORPHOLOGY,

OR

COMPARATIVE ANATOMY.

CHAPTER I.

GENERAL MORPHOLOGY.

General Remarks.—The functions of plants being comparatively simple, and, to speak in general terms, limited to those of nutrition and reproduction, the physiological classes of organs are few. The immense diversity which presents itself in the Vegetable Kingdom depends chiefly upon varieties in the form of organs performing similar functions. In addition to this, the organs of plants are displayed externally, not enclosed in cavities or surrounded by an integument or shell like that of animals, so that the external forms of plants furnish a guide to the discrimination of their most essential characters.

Plants are destitute of the nervous system and the organs subservient to it, and are without the connected system of blood-vessels, by which, in the majority of animals, the unity and interdependence of the nutritive processes are maintained. Plants consist simply of organs of absorption, assimilation, respiration, and reproduction, all composed of comparatively uniform elementary tissues, and supported by a solid framework or skeleton, which is more strikingly developed according to the number of organs associated in one community, and more diverse in its mode of construction according to the variety and complexity of the physiological kinds of organs.

The organs of plants are not only of few physiological kinds, but their variations in form depend on secondary modifications of a very few fundamentally diverse elements. The object of Vegetable Morphology is to ascertain what these elements are, and to trace

out the laws under which they acquire the different forms which they present in fully developed plants.

The methods of Morphology consist in the comparative study of the forms of organs throughout extensive series of plants, the study of malformations arising from arrested, excessive, or perverted growth *(teratology)*, and the study of the progressive development of plants from their embryonic forms (*organogeny*).

Simplest Plants.—The simplest plants (fig. 1) consist of solitary *cells* or bladders of membrane containing a viscid fluid called *protoplasm*, in which latter the vitality of the plant is concentrated. By the aggregation of such cells into threads, tubes, plates, spheres,

Fig. 1.

Simple cellular plants.
A. Yeast-plant vegetating. C. *Penicillium glaucum.*
B. *Aspergillus glaucus.* D. *Mucor Mucedo.*
Magnified 200 diameters.

and other forms (fig. 1, A, B, C, D), a gradually increasing complexity is brought about.

Higher Plants.—What are called the higher classes of plants, those most familar to uninstructed persons, are constructed of precisely the same elements, but exhibit the greatest morphological complexity. The highest class of plants have conspicuous flowers,

as in a rose or a tulip, and in their fruit or seed-vessel are one or more *seeds*—hence the name *Phanerogamia*, or *Flowering Plants*. The complexity of their structure arises not from the number of the organs, but from the more clearly defined limitation of the various physiological functions to the different organs, which are thus more specialized. At the same time the organs are, anatomically speaking, more intimately combined together into a connected whole, and the reproductive powers are more individualized and concentrated at particular centres.

The foregoing may be comprehended by contrasting any ordinary Flowering plant, having distinct blossoms and seed-bearing fruit, with a Fern, where the fruit is borne upon leaves generally of the usual character, and again with a Seaweed or a Lichen, in which there is not even any distinct separation between stem and leaf-structures, and wherein no leaf-buds exist.

In Flowering plants we readily distinguish, in all stages of life beyond the very earliest, two distinct kinds of growth, viz. a stem or axis, from the sides of which proceed lateral organs, of various, but always definite kinds and forms, such as leaves, &c., which become what are called its appendages. In Seaweeds, Lichens, and Fungi there is no really similar diversity of parts: the axis alone is represented, always devoid of leaf-buds, and therefore of proper appendicular organs, the axis itself assuming most varied forms, often more or less approaching those of true leaves, but never exhibiting a distinct separation into two kinds of vegetable structure such as characterizes the higher plants. A distinctive name is given to that class of axes which exist without appendicular vegetative organs. Such products as the leaf-like expansion of Seaweeds, the scale-like plates or crusts of Lichens, or the flocculent "spawn" of Fungi, performing at once the functions of stem and root and leaf, represent what is technically termed a *thallus* (fig. 1). Plants characterized by the possession of this kind of vegetative structure are called Thallophytes, and are contrasted with all the higher plants exhibiting the coexistence of stem and leaf, which are called Axophytes or Cormophytes (from *cormus*, a stem).

But the Cormophytes are again distinguishable into two very well-marked groups, by the characters of the reproductive organs, which, moreover, connect the lower of the two groups with the Thallophytes. The Thallophytes and the lower Cormophytes (including Mosses, Ferns, and allied classes) are reproduced by *spores*, simple structures performing the office of a seed, but in which no *embryo* or rudimentary plant exists at the period when they are thrown off by the parent. The higher Cormophytes are reproduced by true *seeds*, which are far more highly organized bodies than spores, and

which are especially characterized by the presence of an *embryo*, or rudimentary plant, which is developed within them while the seed is still contained in the parent fruit. The latter division also is characterized by the possession of flowers, while the spore-bearing Cormophytes are flowerless, like the Thallophytes.

By far the greater portion of the plants useful to man belong to the Phanerogamous division; and this includes also the most conspicuous and familiar forms of vegetation, those most easy to procure and most easy to study. Hence it is desirable that the Flowering plants should occupy a principal place in an elementary work, and, moreover, that they should be examined in the first instance, before the student is led into the study of the more obscure and minute characters of the *Cryptogamia*. But the study of Cryptogamous plants is quite indispensable to the physiologist; while it forms a most interesting department of the morphology of plants. It will be found most convenient, however, to defer the study of the *Cryptogamia* till after a general acquaintance has been obtained of Flowering plants.

CHAPTER II.

MORPHOLOGY OF THE PHANEROGAMIA.

Sect. 1. General Observations.

General Construction of Flowering Plants.—In any ordinary Flowering plant we may readily recognize some of the most important characters of the organization. Taking the plant as a whole, we find a *stem*, furnished below with *roots* to fix it in the ground and absorb nourishment, and clothed above with green *leaves*, which are known to be the organs of respiration and digestion. Taken together these constitute the system of *vegetative organs*, more or less complicated in their development and arrangement in different cases, and concerned in the nutrition and enlargement of the individual plant (in the familiar sense of that term). At certain seasons we find, superadded to the foregoing, a system of organs constituting the *inflorescence*, and consisting of the *reproductive organs*, provided for the production of *seeds* (the "eggs," as it were, of plants), from which new independent individuals may be raised.

The *inflorescence* consists of one or more *flowers*, which, as will be shown hereafter, are composed of various kinds of peculiarly modified foliar appendages, or *phyllomes*, more or less blended together into compound organs. For our present purpose it will suffice to describe the general and essential characters of the parts found in true flowers.

The outer covering of complete flowers consists of a circle of leaf-like organs, most frequently of green colour, and often forming a kind of cup; this cup or circle of leaf-like organs is called the *calyx*, and its component parts are the *sepals*. Within the calyx of complete flowers we find one or more circles of ordinarily larger, but more delicate, and generally brightly coloured leaves; these are likewise united together below in many flowers: they form collectively the *corolla*, and the individual parts are called *petals*.

Fig. 2.

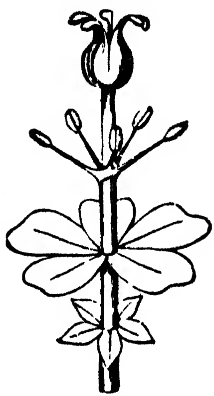


Diagram illustrating the composition of a flower, of four circles of organs—sepals below, followed by petals, stamens, and carpels, all arising from a prolonged axis or thalamus.

Examples of the above may be found in the Heartsease, the Wallflower, the Primrose, &c., where there exist a green calyx and a coloured corolla. In the Tulip the outer parts of the flower consist of six similarly coloured organs, resembling ordinary petals; while in the Dock they are six greenish sepal-like organs. A close examination shows, however, that both kinds of organs stand in two circles of three, one within the other: hence many authors regard them as representing a calyx and corolla of like structure. Other authors give the double circle the collective name of *perianth* or *perigone*.

The *calyx* and *corolla* have no essential share in the production of the seeds; they merely surround and protect the more important organs, either temporarily, or as entering more or less into the composition of the fruit, and sometimes they serve to attract and retain the insects by whose agency the flower is fertilized and the seed formed. The collective term *floral envelopes* is commonly applied to the calyx and corolla taken together; and either one or both of these may be absent in flowers which are nevertheless perfectly capable of producing seeds.

Within the petals is placed the *andrœcium*, consisting of the *stamens*, or male organs of flowers. Each stamen consists of more or less club-shaped bodies called *anthers*, usually supported upon thread-like stalks called *filaments*. The essential character of an anther

is that it contains, and ultimately discharges, the fine dust-like sperm-cells or fertilizing globules called *pollen.*

The centre of the flower is occupied by the *gynœcium* or *pistil*, the female or seed-bearing part of the flower. Pistils are formed of foliar organs corresponding to sepals, petals, and stamens, and called *carpels*; but these are not always so readily distinguishable, on account of their varying number and degree of union, consequent upon their being crowded at the apex of the flower-stalk. The distinguishing character of a carpel is that it bears *ovules* or rudimentary seeds containing germ-cells.

As the stamens furnish the pollen by which the germ-cells are rendered fertile, the two sets of organs, stamens and carpels, are considered *essential organs* of flowers, without which the purpose of the whole structure could not be performed.

In some flowers, such as those of the Hydrangea and the Snowball-bush (*Viburnum Opulus*), there is a tendency in cultivation to the abortion of the stamens and pistils; so that the flowers become *neuter*, or totally barren. But in many plants it is the natural condition for the stamens to occur in distinct flowers from the pistils, so that the individual flowers are imperfect, male or female: we have examples of this in the plants of the Cucumber family, and also in most of our native forest-trees, such as the Oak, Beech, Hazel, or even on entirely different plants, as in the Willow and Poplar, &c.

The *carpels*, the essential organs of a female flower, occur in two conditions in Flowering or Seed-bearing plants; and these two conditions form the basis for the primary subdivision of this group.

In by far the majority of flowers the carpels are folded up and their edges united so as to form hollow cases, in the interior of which the ovules are enclosed. In such instances the pistil is divisible into regions, of which the lower hollow portion, called the *ovary*, is the most important: very frequently a stalk-like process, the *style*, is prolonged upward from its summit, terminating above in a more or less thickened head, called the *stigma*, which marks the position of an orifice leading down through the tubular or spongy tissue of the style into the cavity of the ovary. In many cases the *stigma* is seated immediately upon the top of the ovary, without an intervening style (Poppy, Tulip). Plants bearing their ovules in such closed ovaries are called *Angiospermous*, or covered-seeded.

In Pines, Firs, the Yew, Juniper, and in the exotic family of the Cycads, the sexual organs occur in distinct flowers: and these flowers are not only devoid of proper floral envelopes, but are reduced respectively to single stamens and single carpels, mostly collected into male and female *cones*. The anthers of the male cones

produce *pollen*, and the carpels of the female cones produce *ovules*; but the carpels occur in the form of open scales, and the ovules are borne upon the surface or the free margins of the carpels, so that the pollen reaches them at once, without passing through a stigma and style. Plants with flowers of this kind, with which are also associated many peculiarities in the mode of development of the embryos, are called *Gymnospermous*, or naked-seeded.

Much difference of opinion still exists among botanists as to the true nature of the female flower in Gymnosperms; but for the present the above explanation will suffice for the student.

The *Angiospermia*, comprehending the great body of the Flowering plants, are separable into two very natural groups, which are plainly distinct in the mass, although many complex relations exist between them. Distinctive characters of the two divisions may be found in many parts of the organization of the majority of the plants; but the most general difference is that which occurs in the structure of the *embryo* contained within the seed.

In one division we find that the seeds, with few exceptions, contain an *embryo* in which we may distinguish *two* rudimentary leaves, or *cotyledons*, applied face to face, and having the terminal bud, or growing-point of the stem, enclosed between them. In the other division the embryo presents but *one cotyledon*, or seed-leaf, more or less rolled round the bud, like a sheath. The plants of the first division are called *Dicotyledonous*, those of the second *Monocotyledonous*.

Dicotyledons and Monocotyledons are naturally divided from each other not only by the general characters of their mode of germination, but by the structure of their stems, the arrangement of the skeletons or veins of their leaves (net-veined in Dicotyledons, parallel or straight-veined in Monocotyledons), and the number of organs in the circles of the flowers (generally in fours or fives in the one case, and in threes in the other). These distinctive characters will be more fully considered hereafter.

The ripe seed of the Gymnospermia is very much like that of Dicotyledons; but the leaves of the embryo are either more numerous, or if but two are present, they are sometimes, but not always, slit into lobes, whence these plants have been called Polycotyledonous.

The germination of the seeds of all the Flowering plants consists in the emergence of the *embryo*, more or less completely, from the seed, and in the unfolding of its rudimentary vegetative organs—the *radicle*, the *cotyledonary leaf* or *leaves*, with the *stem* supporting them, the *tigellum*, which is sometimes very short, but which termi-

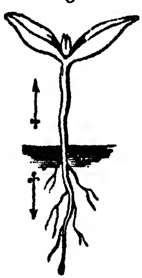
nates above in a little bud called the *plumule*; the subsequent unfolding of the plumule gives birth to the first true leaves (fig. 3). Here, then, we have represented all the kinds of organs of vegetation which will form the first objects of our investigation, namely the *root*, the *stem*, and the *leaf*, together with the *buds*, or compounds of rudimentary stem and leaves, which occur at all growing-points of the plants possessing these organs.

The phenomena of germination may be conveniently observed by sowing some Turnip-seeds and Oats in a saucer of moist sand covered by a bell-glass. The structure of a dicotyledonous seed may also readily be observed by soaking a Pea or a Bean in water, and then peeling off the rind, when the parts of the embryo, as above described, may be readily observed.

Sect. 2. The Root.

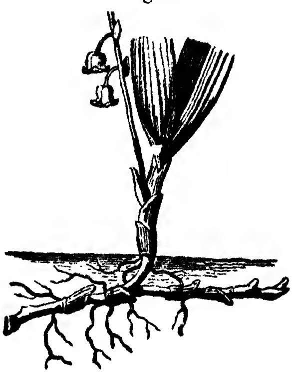
Definition.—The root may be described in general terms as the descending portion of the axis, destitute of leaves, buds, flowers, and green colouring-matter, but provided originally with a minute "root-cap" at its extremity. Another character of general although not of universal application is, that it is the part of the plant which penetrates into the soil, and which serves at once as an organ of attachment and of nutrition.

Fig. 3.



A seedling Dicotyledonous plant, with an ascending axis or tigellum and a descending axis or radicle, two cotyledons, and a terminal bud or plumule.

Fig. 4.



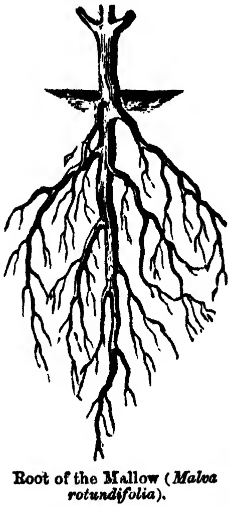
Lily of the Valley (*Convallaria majalis*), with a subterraneous creeping stem and adventitious roots.

The simplest representative of the root is a mere cell or tube capable of absorbing fluids. Such organs are found in the simplest plants. The definition above given applies to the more highly organized plants; but even in these the *root-hairs* are mere cells of the character just mentioned.

Exceptions.—The statement that roots descend is subject to a few exceptions in the cases of the lateral ramifications of roots, and of the lateral roots formed by parasitical and by certain climbing plants, which often retain their original direction, making a more or less obtuse angle with the stem from which they rise. In some Cycads and Arads the root-branches ascend vertically. These exceptions are less numerous than the deviation of the stem from its general character as the ascending part of the axis, since in a large number of perennial plants the direction of the main stem is constantly horizontal. Stems of this kind are of frequent occurrence among perennial herbaceous plants, and are ordinarily termed by gardeners "creeping roots:" for example, those of the Lily of the Valley (fig. 4), Garden Flag, Couch Grass, &c. Roots, as a general rule, are destitute of leaves and leaf-buds, which fact serves to distinguish them from *rhizomes* or *root-stocks* (STEMS). But the distinctions between root and stem are not absolute: many exceptional instances occur, and some transitional ones; thus, under certain circumstances, roots, as indeed every part of the vegetable structure, may be made to form buds, but always from the sides, never from the end as in stems. Some trees are especially prone to this, and may be propagated by cuttings of the root, such as *Pyrus japonica, Maclura aurantiaca*, the Plum-tree, &c. The root of *Anemone japonica* likewise produces buds very readily. The roots of *Neottia* bear leaves, while, on the other hand, some Orchids, as *Epipogon Gmelini* and *Corallorhiza innata*, and some Bromeliads have no roots.

Origin of the Root.—The true root of the embryo plant is the downward continuation of the axis; but the original radicle, the real inferior extremity of the axis in the Monocotyledons and in the stem-forming Flowerless plants (such as the Ferns), in most cases speedily ceases to grow, and the efficient roots are really lateral organs. Where the primary radicle is developed, we have a true root (fig. 5); but the roots which are produced from the *sides* of stems, or from leaves, are termed *adventitious* roots (fig. 4).

Fig. 5.



Root of the Mallow (*Malva rotundifolia*).

The axial root may be seen well in any seedling Dicotyledonous plant, as in a young Bean or Turnip; and by watching the germination of a few seeds of such plants, the development of the radicle into the axial root may be readily traced. The axial nature of the root is clearly evident in the full-grown plants of most annual garden species of Dicotyledons; and in shrubby and arborescent perennials of this class the axial root is persistent, growing by annual increase into a large woody mass, proportionate to that of the ascending stem or trunk.

The origin of *adventitious* roots may be observed in germinating seeds

of Monocotyledonous plants, such as grains of Oats, Wheat, &c.; but their essential character may be still more clearly distinguished in plants which form adventitious roots on well-developed stems and bud-like structures. The fibrils which sprout from the joints of the stems of numerous creeping plants (Ground-Ivy, Mint, Sand-Sedge, &c.), the clamping roots of Ivy-stems, the roots of an Onion-bulb, as well as those formed from slips or cuttings, &c., afford familiar examples of adventitious roots.

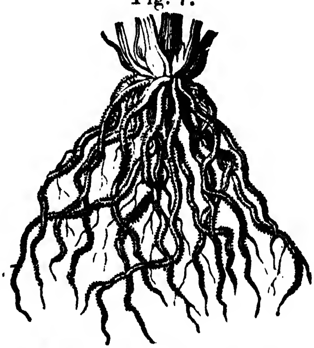
Fig. 6.

Fusiform tap-root of the Carrot (*Daucus Carota*).

Ramification.—Where the branches of the root are comparatively small and the central axis is both thick and considerably elongated, the root is called a *tap-root* (fig. 6); where the branches are developed so that the principal axis is lost as it were in its own ramifications, the root is called *fibrous* (fig. 5). The branches issue from the main root in succession from above downwards (not from below upwards as in stems), and are, in the first instance, regularly arranged in rows one above another. The number of rows varies in different cases; and the regularity of disposition is soon lost.

When the tap-root exists in herbaceous plants, it often exhibits a more or less succulent character, and becomes a *tuberous root*, as in the biennial Turnip, Carrot, Beet, &c., where this organ is peculiarly developed in the first season of growth, to serve as a reservoir of nutriment. The tendency of such plants to exhibit this character in excess under the influence of stimuli renders them extremely valuable for economic purposes. The fibrous rootlets upon the surface of tuberous tap-roots, like the Carrot, Parsnep, &c., appear to be mostly true roots. A distinction is made, in describing tuberous roots, between those which are *fusiform*, as in the Carrot, and those which are *napiform*, as in the Turnip. A woody tap-root is found in many forest-trees, as, for example, in the Oak; but here the branches share more extensively in the increase in size, and their direction tends more to the horizontal. Fibrous roots are particularly characteristic of plants growing in light and sandy soils or in water; the perennial, woody forms are especially characteristic of shrubby Dicotyledons.

Fig. 7.



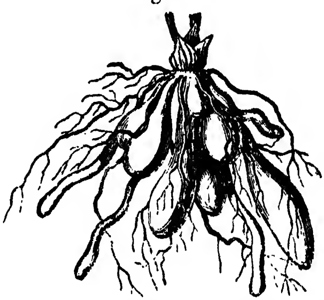
Tuft of fibrous adventitious roots of a Grass.

In general terms it may be stated that the form assumed by the roots, whether true or adventitious, is in direct relation to the nature of the medium in which they grow and the purposes they have to serve as feeding roots, hold-fasts, or reservoirs of nutriment.

Adventitious Roots (figs. 4, 7) are specially characteristic of, though by no means confined to, Monocotyledons and Flowerless plants, since their radicles are usually arrested in their growth; they are also necessarily the only kind which can occur upon specimens of Dicotyledonous plants which have been raised, not from seeds, but from cuttings, layers, tubers, &c. They arise from the *side* of the stem which gives birth to them, and most readily in the vicinity of buds or leaves.

Adventitious roots are very variable in form and consistence. They may be fibrous (fig. 7) or tuberous (fig. 8), and are not uncommonly of intermediate character in the Monocotyledons, consisting of more or less thick fleshy fibres. Either the fibrous or tuberous form may occur exclusively in groups of adventitious roots, or such groups may contain roots or rootlets of both kinds. In arborescent Monocotyledons the adventitious roots acquire a woody character and great size; in herbaceous Monocotyledons they are commonly annual, or, if tuberous, biennial.

Fig. 8.



Fasciculate adventitious roots of *Ranunculus Ficaria*, partly fibrous, partly tuberous.

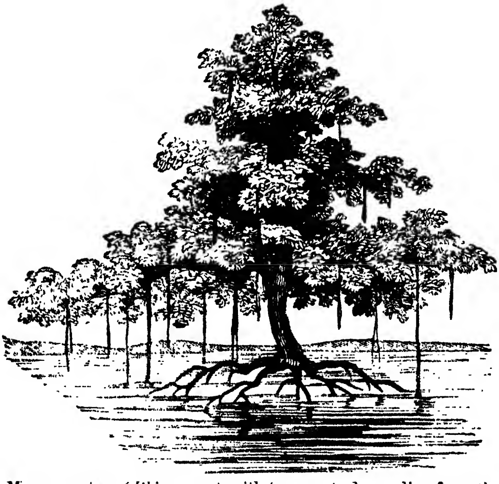
The *fibrous* adventitious roots of Monocotyledons are generally soft, much elongated, and little divided, like those at the base of bulbs of the Hyacinth, Onion, &c. (fig. 17). A mixture of fibrous and tuberous adventitious roots, forming what is called a *fasciculate* root, occurs in *Hemerocallis*, and in *Ranunculus Ficaria* (fig. 8), in which, as in the plant last mentioned, the structure is still further complicated by the existence of buds, as explained further on under the head of Tubers. A peculiar modification of this structure is found also in most terrestrial Orchids. In *Spiræa filipendula* the fibrous roots exhibit tuberous thickenings at intervals.

Root-hairs.—The youngest parts of rootlets, whether branches of axial roots or adventitious roots, often exhibit a coat of delicate cottony *root-hairs*, which are thread-like growths from the epidermis (*trichomes*), and are thrown off in perennial roots when the epidermis gives place to the rind.

The nature of the root-hairs will be explained under the head of the Anatomy of Roots. Examples may be found in seedling plants of mustard, in potted Geraniums (*Pelargonium*), or in the roots of many Monocotyledonous bulbous plants and Grasses growing in damp places.

Media in which Roots grow.—Roots of ordinary plants bury themselves in the soil; those of water-plants, usually more succulent in their texture, penetrate the mud, as in the Water-lilies, or hang freely down in the water, as in Duckweed and the Water Crowfoot. A number of plants exhibit what are called *aërial roots*, which are always adventitious: and these may be either the

Fig. 9.



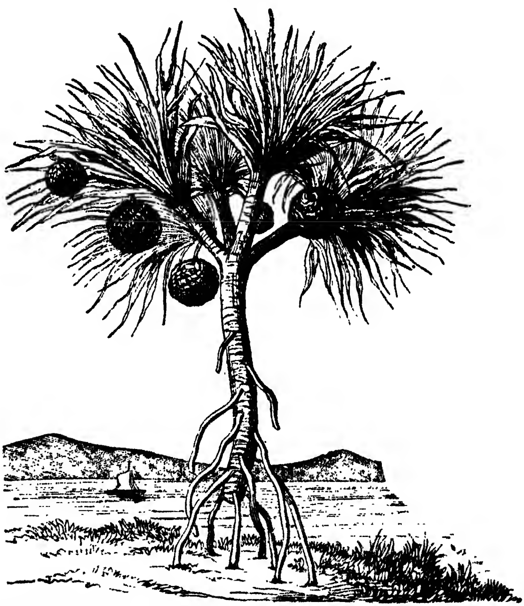
Sketch of a Mangrove-tree (*Rhizophora*), with true roots descending from the branches.

sole radical organs of the plant, or roots developed high above the ground but growing down to reach the soil, or they may be converted into organs of support for a weak stem. In true parasitical plants, like the Mistletoe, the roots, more or less developed, attach themselves to, and become organically blended with, the roots or stems of other plants.

The plants called *epiphytes*, such as the aërial Orchids, various Araceous plants, and members of the Pine-apple family, are possessed of aërial roots alone. The stem of such plants rests upon some foreign body, such as the branch of a tree, totally unconnected with the earth, and produces long adventitious roots which hang suspended in the atmosphere. Roots

developed in the air, and subsequently descending, present themselves in various conditions. One of the most remarkable is that which is observed in the Mangroves (fig. 9) (Rhizophoraceæ), where the seed germinates in the fruit while the latter is still attached to the tree, and drops down its long radicle until it reaches the mud in which these trees grow, so that the stem of the young plant is enabled to establish itself firmly in the uncertain soil before it detaches itself from the parent. This is an axial root. In the Banyan tree (*Ficus indica*) adventitious roots are frequently developed on the branches, which, descending to the earth, pene-

Fig. 10.



Pandanus odoratissimus, the Screw-pine, with adventitious roots supporting the trunk.

trate into it and become supporting columns, which ultimately assume the appearance of trunks, and give the tree the appearance of a group or even a grove of trees united together at their heads. The roots of the arborescent Monocotyledons partake to a certain extent of the same character; and those of Palm-trees are observed to arise successively one above another in a spiral course near the base of the stem, growing outwards and downwards to penetrate the ground, the older ones ultimately decaying. In the Screw-pines (*Pandanus*, fig. 10) this is still more striking and distinct, as the spiral line which they form is more open,

and the roots arise a long way up the stem; here also the older roots and the base of the stem decay, so that the whole plant comes to be supported by the lateral adventitious roots, as on so many props. Aërial roots becoming organs of attachment may be seen in the climbing stems of Ivy, of the garden Bignonia (*Tecoma radicans*), &c.

Parasitic Plants developed from seeds present, in their earliest stages, a radicle which in some cases becomes developed, in others not, or only in a peculiar manner. Some germinate in the usual way, in the earth, and their roots seek out those of their proper nurse plants, to which they attach themselves organically, others superficially or by penetrating deeply into the interior; in such cases they may be wholly parasitic, as in the leafless Broom-rapes (*Orobanchaceæ*), or only partly dependent, as in *Thesium*, *Rhinanthus*, and *Melampyrum*. Others germinate in the usual way in the soil; but their young stems attach themselves to those of other plants by adventitious roots developed at the points of contact, while the lower part of the parasite, connected with the ground, soon dies away, as in the Dodder (*Cuscuta*). The woody parasites, Mistletoe (*Viscum*), *Myzodendron*, and others, are developed from seed upon the spot where they are attached. In the Mistletoe, the seed clings by its viscid pulp; in *Myzodendron* by coiled hairy arms; and when the radicle sprouts, it drives its way through the rind of the nurse plant until it reaches the cambium layer, where it connects itself organically, becoming grafted exactly like a budded rose. No further development of root-structure occurring here, the full-grown plant appears rootless, and like a branch or graft upon the nurse tree. The earlier stages of growth of the Rhizantheæ, root-parasites composed chiefly of inflorescence, are not known; probably they are analogous to those of *Viscum* in the first instance, but with the addition of horizontal growths of stem-structure beneath the bark of the nurse plant.

Characters presented by the Root, &c.—The points to be specially attended to in studying and describing the root, such as the form, ramification, &c., may be gleaned from what has been before stated and from the Section on the Description of Plants.

Sect. 3. The Stem.

Definition.—The stem is the ascending portion of the axis of a plant. It is usually characterized by its growth taking place in a direction contrary to that of the roots, and by bearing on its sides regularly arranged leaves or modifications of leaves, forming the *lateral* or *appendicular organs*. The term *caulome* is applied in a comprehensive sense to any stem or branch or to any modification of those organs bearing leaves or modified leaves, *phyllomes*.

Exceptions.—An exception to the ascending growth occurs in the case of creeping stems, where the main axis takes a more or less horizontal position; but the first shoots of such plants, developed from their seeds, ascend, and the secondary axes, which bear the efficient leaves, assume the

erect position, as is seen in the tufted habit of growth of plants with a subterraneous main stem. (See also p. 15.)

Buds.—Every stem is developed from a *bud*, which consists of a conical rudiment or growing-point of the stem bearing rudimentary leaves crowded upon its sides. The primary bud of the stem of Flowering plants presents itself as the *plumule* (fig. 3) of the embryo; and so long as this axis continues to grow, a bud (the *terminal bud*) is found at its extremity. The branching of a stem depends upon the development of lateral buds, which, as a general rule, appear only in the *axil* or upper angle between the base of a leaf and the stem, whence they are called *axillary buds.*

There is in many embryo plants a small portion of the axis intermediate in structure as in position between the true root and the true stem (fig. 3). This "*hypocotyledonary axis*" or *tigellum* sometimes gives off shoots, by which it may be distinguished from roots; moreover it is either cylindrical or tapers upwards, while a root tapers in the opposite direction. This hypocotyledonary axis forms the trunk of the extraordinary plant called *Welwitschia*, hereafter described.

Fig. 11.

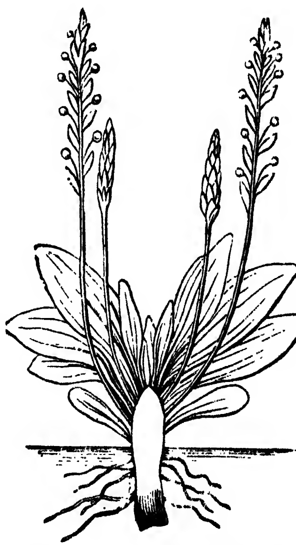


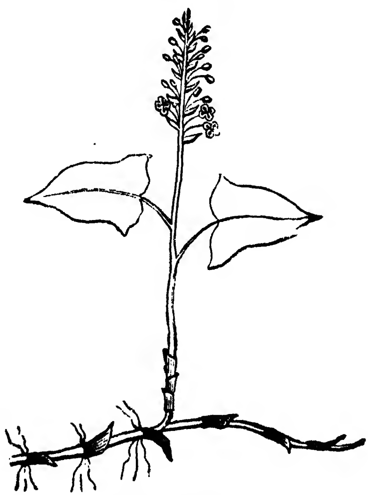
Diagram of *Plantago media* bearing leaves crowded on a stem with undeveloped internodes. The short stem seen in section.

Nodes and Internodes. — The place whence a leaf arises marks the position of a structural region endowed with special physiological activity; it defines externally a point where the internal tissues have a peculiar arrangement. Hence a particular name is applied to it, that of *node*. Sometimes a kind of articulation of the stem occurs at this point, but not as a general rule. The intervals between the points of origin of leaves are called the *internodes*. In buds, the internodes are not yet developed. In a large majority of ascending stems the internodes become considerably developed, so that the leaves ultimately appear stationed at distinct intervals. In many subterranean stems, at the lower part of the stems of many herbaceous plants (fig. 11), and in the trunks of many of the arborescent Monocotyledons, the internodes never become much lengthened, and the leaves in consequence appear

closely packed and more or less overlapping in the full-grown plants. Such plants are sometimes, but erroneously, called *acaulescent* or stemless plants.

The relative development of the internodes is next in importance to the order of arrangement of the axillary buds in affecting the general forms of stems. A clear idea of the conditions may be obtained by examining, in the first instance, what occurs in the unfolding of the bud of such a tree as the Horse-chestnut. In the bud the enveloping scales, the rudimentary leaves, and even the blossom may be distinguished, crowded on the undeveloped axis. As the leaves emerge and expand, they become separated from each other by the elongation of the internodes of the stem, until at length they stand at considerable distances along the sides of a shoot several feet long. This may be illustrated by comparing it to the separation of the joints of a telescope, when its lengths of tubes are successively pulled out. Examples of permanently *undeveloped internodes* are seen in the rosette-like offshoots of Houseleeks and of many other herbaceous perennials—in the first season's growth of such plants as the Turnip, Carrot, Canterbury-bell, and indeed of most biennials, where the leaves all appear to arise from the root—in the bulbs of many Monocotyledons, such as the Crocus, Hyacinth (fig. 17), &c. In these cases the flowering axis which subsequently appears often develops its internodes considerably, and rises as a tall stem. An intermediate condition is met with in stems which are elongated, but have the leaves closely overlapping, as in the common Stonecrop, many Coniferous trees, many Palms (fig. 33), &c.; and a similar condition exists in the subterraneous root-stocks of various plants, where the imperfect sheathing leaf-scales succeed each other at short intervals.

Fig. 12.



A plant of *Smilacina bifolia* with a creeping rhizome bearing *leaf-scales*, an erect *leafy* stem, and an inflorescence with *bracts*.

Regions of the Stem.—In the embryo of a Flowering plant it is scarcely possible to define the limits even of the stem itself, which loses itself above in the plumule, and below in the radicle. But in fully-developed stems, a general division into three regions may be distinguished, according to the kind of lateral organs which they bear, viz:—

1. The *Leaf-scale* region (fig. 12), which is mostly subterranean

in its habit, and presents itself with more or less of the external appearance of a root, of an enlarged fleshy bud, or of a combination of these two. The leaves upon this are never green, but are of fleshy or membranous texture and simple forms. Leaves of this character are found on the outside of buds.

2. The *Leaf* region, forming the ascending stem of plants generally, especially characterized by the green colour and great development of the foliage.

3. The *Bract* region, which is also known as the *Inflorescence*, is distinguished by its smaller, more delicate, and sometimes coloured leaves, the axillary buds of which produce flowers.

The extent, both positive and relative, in which these regions are represented is different in almost every plant; but a few general statements may be made serving to illustrate the subject. The leaf-scale region is developed chiefly in *herbaceous perennial* plants; and the principal modifications of it will be examined below under the heads of Rhizomes, Bulbs, and allied structures. It may be observed that the leaf-scales or abortive

Fig. 13.

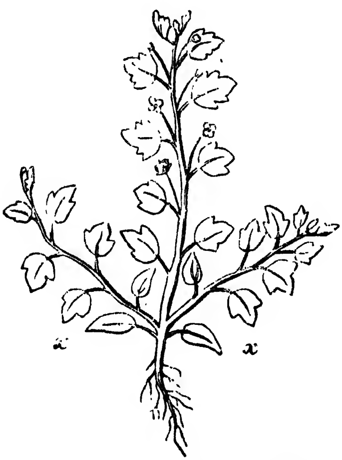


Diagram of a plant of *Veronica hederæfolia*, where the leaf-scale region bears the cotyledons *x*, *x*, and the rest of the stem is a true-leaf stem with flowers in the axils of its upper leaves.

Fig. 14.

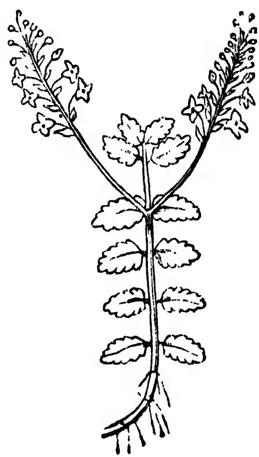


Diagram of a plant of *Veronica Chamædrys*. The lower part is a true-leaf stem, and its branches are bract-stems or inflorescences. The roots proceeding from the stem are adventitious.

foliaceous organs are almost exclusively composed of the stalks or sheaths of leaves, without any part corresponding to the blade; exceptions to this, illustrating the rule, occur in tunicated bulbs like the Hyacinth

(fig. 17), where the inner scales bear a green blade standing out free at the top of the bulb, and again in various subaquatic Grasses with creeping stems, in which the lower parts of the annual shoots often exhibit large open sheaths with small rudiments of blade at their summits. The region bearing perfect leaves forms the principal part of the axis in arborescent plants, where the leaf-scale region occurs only at the points where the protecting scales of the autumn buds are produced. The scars of the leaf-series, crowded together from the non-development of the internodes, are very visible at the base of the yearly shoots of many trees, for example, of the Horse-chestnut: other trees reproduce, as it were, their cotyledons at those points; the Jasmine, for example, exhibits a pair of broad undivided leaves near the base of each annual shoot. In annual plants the leaf-region is predominant, but the bract-region is relatively more developed than in trees; and the same holds good of perennial herbaceous plants. In arborescent plants the bract-region usually does not present itself until the leaf-regions of many years have been formed, and even then it is generally formed from branches of the axis which have a subordinate share in giving the special form to the entire plant; sometimes, however, the form of the ramification is much affected by the position of this region, as in the Horse-chestnut, Lilac, and other trees, where the terminal buds of shoots are developed into an inflorescence, which of course puts a stop to the onward growth at these points.

Fig. 15.

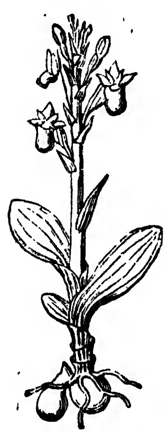


Diagram of a plant of *Ophrys arachnites*. The leaf-scale, true-leaf, and bract regions successively presented in the same axis.

Leaf-scale Region.—The leaf-scaled stem, found especially among *herbaceous perennial* plants, or such as live for several years without forming a permanent woody stem above ground, is seldom continuous with an axial root; on the other hand, it is very prone to produce adventitious roots, as is natural to its usually subterranean or creeping mode of growth. When its internodes are regularly although slightly developed year after year, it forms an abbreviated stem, horizontal or ascending, either below or above ground. If the main axis persists, producing a few branches each year, and as it grows at one end slowly dies away at the other, a more or less root-like structure is produced, termed a *root-stock* or *rhizome* (fig. 12). If the growth of each axis decays away at regular intervals, so as to isolate the products of the succeeding axes, the result is different, and, instead of a branching rhizome, the axis resolves itself into a number of detached portions, in the form of *corms*. If these detached portions are chiefly composed of leaf-scales, with the undeveloped stem small, so that they represent enlarged buds, they are called *bulbs* (figs. 16 & 17). Another re-

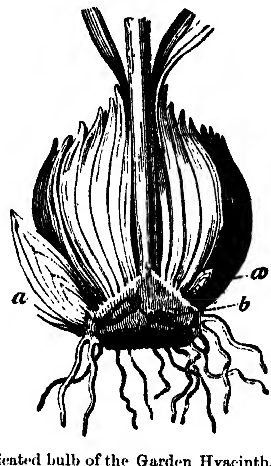
productive structure belonging to the leaf-scale region of the stem is the *tuber* (fig. 19), which consists of a fleshy thickened subterranean axis, arising in the axil of a leaf-scale, having its own internodes considerably developed, so that its leaf-scales are scattered and cover isolated buds or "eyes." Tubers of analogous character are sometimes formed from aërial branches, as in many epiphytic Orchids, where they have a green colour and are known as *pseudo-bulbs.*

Bulb.—The bulb (fig. 16) is a stem remaining permanently in the condition of a bud. Its axis consists of a disk or short conical plate, from the upper surface of which arise leaf-scales of fleshy character more or less overlapping each other and enclosing the points of growth, while one or more circles of adventitious roots are given off from the base (fig. 17). Bulbs are named, ac-

Fig. 16.

Scaly bulb of *Lilium candidum*, with adventitious roots.

Fig. 17.



Tunicated bulb of the Garden Hyacinth, cut through perpendicularly, showing the leaf-scales arising from the abbreviated stem (*b*), and the young bulbils or cloves (*a*, *a*) formed in the axils of leaf-scales.

cording to the character of their leaf-scales, *scaly* or *squamose* when these only partially overlap (Lily), and *tunicated* when the scales form complete sheaths (Onion, Hyacinth). Bulbs produce flowering axes either from the terminal or from axillary buds. They are multiplied by buds developed in the axils of the scales in the form of new bulbs (fig. 17, *a*, *a*), which sooner or later become detached.

When a bulb flowers from its terminal bud in its first season of growth, it is *annual*; when it only strengthens itself by forming scales in the first season, and flowers from the terminal bud in the second, it is *biennial*; when it flowers from an axillary bud, the terminal bud may be developed in the same form indefinitely and form a *perennial* bulb.

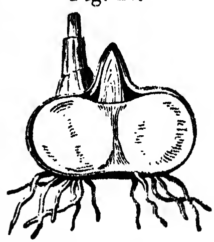
The number of leaf-scales constituting the mass of a bulb varies much in different plants: in *Gagea* and others there exists only one; *Allium oleraceum* has but two; the Garden Tulip and Crown Imperial have comparatively few scales, while the Lilies and the Hyacinth (figs. 16 & 17) have numerous coats or scales. A little explanation is requisite as to the terms *annual* &c. as applied to bulbs. We have an example of what is called an annual bulb in the Garden Tulip. As planted in autumn, it is a bud composed of four or five scales enveloping a central rudimentary flowering stem which terminates the main axis. In the axil of the outer scale there is an axillary bud. As the flowering stem is developed the old bulb shrinks, while the axillary bud becomes more and more perfect; so that, after the flowering season is over, it forms a new bulb, to the side of which the withered remains of the old one are attached. The terminal point of the new bud repeats the flowering, and its outer scale (sometimes the next also) subtends an axillary bud destined to become a new bulb in the next season. Such bulbs are sometimes called *præventitious*, since the bulbous structure of any given axis is formed before the true leaves and flower. The Crown Imperial (*Fritilaria imperialis*) affords an example of a *biennial* bulb. Examined in the autumn, it is found to consist of fleshy scales produced at the lower part of the axis which has just flowered; while a bud seated in the axil of the innermost of these scales is already developed, and by the decay of the old flowering stem has come to occupy the centre of the bulb. In the next season this bud flowers: at first it is surrounded by the scales of its parent axis; but after the flowering is over, these very quickly shrivel up and disappear, the axis which has just flowered giving origin at its base to a number of scales replacing them; and while the flowering stem decays away down to these scales, a new axillary bud is developed in the axil of its innermost or uppermost basal scale. Thus the bulb always bears growths belonging to two seasons on the same axis: the nutrient leaf-scales of each axis are developed upon it *after* it has flowered, and serve for the support of the flower of the next axis. Such bulbs are sometimes called *postventitious*, and may be termed *definite* to distinguish them from the next kind. *Perennial* bulbs differ from the foregoing in retaining the products of the condensed axes of several years in a healthy vegetative condition. Thus, if we examine a bulb of the Garden Hyacinth (fig. 17) when it is flowering by its terminal bud, we find the base of the flowering axis surrounded by several leaves belonging to itself; the whole of them stand in the axil of a scale belonging to the preceding year, which also contains the short remnant of the flower-stalk of that year; and to this scale succeed several more, all belonging to that same axis; these moreover stand collectively in the axil of the innermost of a series of scales belonging to the year before, remains of the flower-stalk of which are

also sometimes visible. Finally, on examining the axil of the innermost green leaf of the present year, we find, nestled between it and the base of the flower-stalk, the bud which is to form the axis of the next year. Therefore this bulb possesses structures or axes belonging to four distinct generations. The bases of the green leaves expand into fleshy sheathing coats after the flowering of the axis which gives rise to them; and the decay of their blades, which extends to the summit of the bulb, gives rise to the ragged or bitten-off appearance of the latter. These bulbs are *postventitious* like the last kind, but may be distinguished from them as *indefinite*.

Corm.—The corm more or less resembles a bulb externally, but consists principally of a stem with little-developed internodes, thickened into a fleshy body, and bearing leaf-buds at one point, either at the summit, as in the Crocus (fig. 18), or at the side, as in *Colchicum*.

The corm of a Crocus examined very early in spring exhibits a primary axis in the form of a roundish mass bearing the adventitious roots below, and giving rise above to one or several tufts of leaves. The bases of the leaves, outside which are a few membranous scales, being at first sunk in the parent axis, these tufts or rudimentary branches are not readily distinguished as secondary axes; but the terminal bud soon grows out to produce the flower. After the flowering is over, the internodes between the scales and the bases of the green leaves become developed both vertically and also horizontally, so as to convert the base of each flowering stem into a new corm. When about half-grown the new corms stand out as globular bud-like structures on the top of the old corm, which is gradually exhausted, and decays away, so as to set its progeny free. In the axils of the uppermost leaves of the flowering stem are developed new buds (which exist even before the corm begins to sprout in spring); and as the new corms are perfected, the buds imbedded in their summits form the rudiments of the leaves and flowers of the next season, sprouting out in the spring, each to reproduce a corm. Hence in a corm taken out of the ground a short time after the flower withers, we find three sets of axes:—1, the withering parent corm; 2, the young corms branching from this, formed from the bases of the flowering stems; and, 3, the axillary buds of the leaves of the latter, forming the resting buds at the summits of the new corms.

Fig. 18.



Corm of the Garden Crocus, cut through perpendicularly.

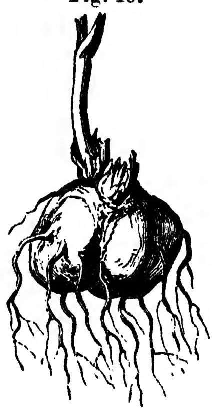
In *Colchicum autumnale* the conditions are somewhat different. When the plant is flowering, in autumn, we find the flowering stem attached to the side of the base of the corm; the flowering stem is surrounded at its base by sheathing scales and rudimentary leaves; in the axils of the two lowest leaves exist minute buds, and the internodes between these leaves are slightly developed. The flowering stem then withers down to the ground, and during the winter the internode between the two buds swells

and forms a new corm, the old one shrivelling up. The leaves appear above ground in the spring, proceeding from the apex of the corm, and the bud at the side of its lower end shoots out to form a new lateral stem, which produces sheaths and rudimentary leaves, and ultimately forms the flowering stem of the next autumn, the base of which repeats the formation of a corm in like manner and shoots up its tuft of leaves in the following spring. The corm being formed from the internode between the buds, the lower of these is, to a certain extent, basilar as well as lateral, while the upper one appears near the top of the perfect corm, rather to one side, near the scar of the old leaves and flower-stalk: this bud may or may not be developed into a corm simultaneously; but in any case it becomes detached from its fellow when the old corm shrivels up, and thus may multiply the plant.

The corm of *Arum maculatum*, examined in spring, exhibits two lobes, with an intermediate constriction; they lie adjoined horizontally: the corm of the past year is shrivelled; the other is solid, and at the summit exhibits sheathing scales enveloping the base of the erect flowering stem. Opening the sheath, which turns upward, we see that the flower arises from a terminal bud, while in the axil of a leaf arising below it exists a bud which is destined to swell up and form a new corm for the next season, the oldest one meantime withering away; so that two generations with the rudiments of the third always coexist; these generations may consist of a greater number of individuals when additional corms arise from the axils of several of the scales of the parent corm.

Tubers.—The stem-tuber is either formed from the base of a stem, or from a branch arising from a subterraneous leaf-scale (fig. 20), developed either partially or entirely into a thick and fleshy mass, by expansion of its spongy structure, its own leaves appearing in the form of rudimentary scales, in the axils of which exist dormant buds, or eyes, capable of producing independent stems when the tuber recommences its development after a season of rest.

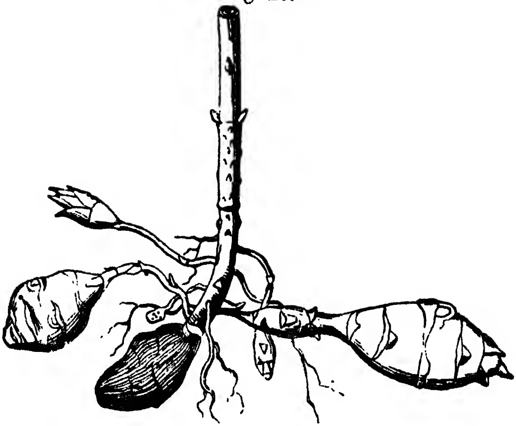
Fig. 19.



Tuber formed at the base of the stem of *Bunium Bulbocastanum*.

Axial tubers occur in many herbaceous plants, as in *Corydalis bulbosa*; when of annual duration, these are essentially the same as corms. The tuber of the Potato is a familiar example of the stem-tuber formed from a branch, in which its characters may be readily observed; a number of leaf-scales at the base of the "haulm" send out subterraneous branches, which at some distance from the point of origin cease to elongate, and swell up into tuberous masses. The tubers of the Jerusalem Artichoke (fig. 20) are analogous productions. Stem-tubers passing more or less into rhizomes form the so-called roots of the Bryonies (*Tamus communis* and *Bryonia dioica*), of the Sweet-potato (*Convolvulus Batatas*), and the

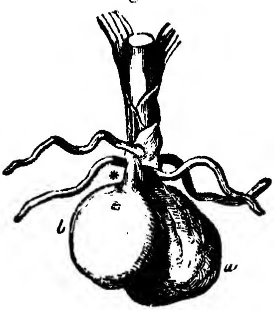
Fig. 20.



Stem-tubers of the Jerusalem Artichoke (*Helianthus tuberosus*).

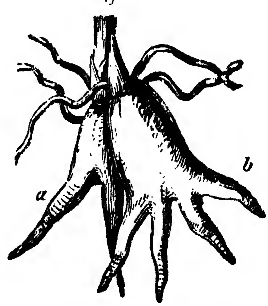
species of *Dioscorea* yielding "yams." The tubers of the terrestrial Orchids are chiefly composed of radical structures. If we examine the twin tubers of *Orchis Morio* (fig. 21), we find one at the base of the flowering stem (*a*), which towards the close of the season is withered, while the other (*b*), crowned by a bud (*), is solid and healthy: in the axil of the lowest leaf of this bud exists another bud in a rudimentary state; and as the oldest tuber shrivels, this swells out and assumes its form, in the next season appearing as the bud-tuber, while its parent becomes the tuber of the flowering stem. The greatest part of the mass of these tubers consists of a swollen adventitious root, which is intimately blended with a few little-developed stem-internodes and the

Fig. 21.



Double root-tubers of *Orchis Morio*: *a*, old tuber; *b*, new tuber with the bud * for the next season.

Fig. 22.



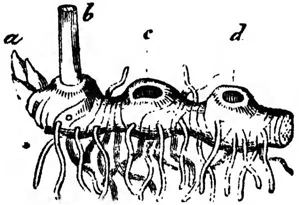
Double palmate root-tubers of *Gymnadenia odoratissima*: *a*, old tuber at the base of the old flower-stem; *b*, new tuber with

terminal bud. In some cases these tubers are rounded; in others they are divided below, so as to become palmate (fig. 22). The tubers of *Bunium* (fig. 19) belong to the root.

Rhizome.—The rhizome or root-stock is a body composed of an indefinite number of corm-like axes permanently connected together, so as to form an elongated, root-like stem, more or less clothed with leaf-scales (fig. 23). Its internodes are generally little developed; sometimes, however, regions with developed internodes alternate with others wherein they are undeveloped, giving a nodose character: when it has the internodes much developed (figs. 12 & 25), it approaches in character (through "runners" &c.) to creeping leafy stems. Its texture and appearance vary from herbaceous or fibrous (fig. 25) to tuberous (fig. 23); its direction is usually horizontal, though in some cases it is vertical (fig. 24); and in the majority of cases it grows under ground.

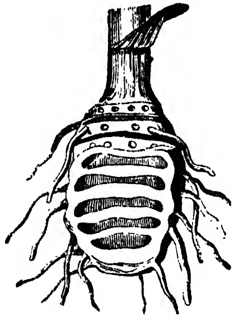
Examples of the rhizome are very numerous among herbaceous perennial plants, both Dicotyledons and Monocotyledons. The Iris affords an example of a tuberous rhizome which may be understood by comparing it with a corm like that of *Arum maculatum*, and by supposing that the older portions of this survive for many years, so as to form a creeping, more or less branched mass. The Solomon's Seal (fig. 23), Sweet-flag (*Acorus*), Ginger, Water-lily, &c. afford other well-known examples.

Fig. 23.



Rhizome of Solomon's Seal (*Convallaria polygonatum*): *a*, bud for next year; *b*, flowering stem of the present year; *c* & *d*, scars of the flowering stems of two preceding years.

Fig. 24.

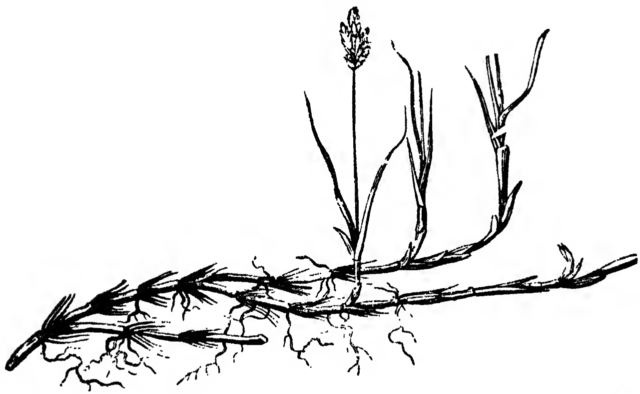


Vertical rhizome of *Cicuta virosa*, cut through perpendicularly.

In some of these (called *definite rhizomes*) the flowers appear to be produced by terminal buds, which take an ascending direction and lose themselves in the inflorescence, the onward growth of the stem being effected by means of axillary buds. In others (*indefinite rhizomes*) the growth is continuous by the formation year after year of a terminal leaf-bud. Rhizomes of more solid texture, but of analogous construction, occur in many Ferns, as in *Aspidium Filix-mas*, also in most of the Rushes

(*Juncus*), and a great variety of herbaceous Dicotyledons, such as the Primrose, &c. Certain widely extending creeping plants afford examples of rhizomes with developed internodes, as the Sand-Sedge (fig. 25), the wire-like rhizome of which extends for many yards under the loose sand, sending up leafy shoots at regular intervals; the stems of Couch-grass, of various Mints, and other Labiate plants; as also of certain Ferns, such as *Lastræa Thelypteris*, and of the Horsetails (*Equisetum*), &c. When the rhizome is erect it has much of the aspect of a root; and the ordinary form was termed by the old writers a *premorse* root, the decay of the lower end giving it the appearance of having been gnawed off. Examples of this are not uncommon, as in the *Scabiosa succisa*—in various Umbelliferæ, as *Cicuta virosa* (fig. 24), where the abbreviated internodes form discoid chambers corresponding with the fistular internodes above, and in the Lady-fern (*Athyrium Filix-fœmina*), which consequently rises above ground like a dwarf tree-fern. In *Sparganium ramosum* we meet with a curious alternation of condensed and elongated internodes, so that the rhizomes appear to consist of a number of corms connected together by branches into an erect candelabrum-like assemblage.

Fig. 25.



Sand-Sedge (*Carex arenaria*), the creeping fibrous rhizomes rooting at the nodes and sending up flowering stems.

The true-leaf Region.—The leafy stem, or region bearing green foliaceous organs, grows above the soil, either in air or water, exposed to the influence of light. Its form and structure are extremely varied, depending chiefly on the mode of development of the internodes, the arrangement of the leaves and mode of development of the buds, and the extent to which its existence is prolonged. The first cause regulates to a great extent the form of the axis, the second the mode of ramification, and the third the size and consistence of the full-grown organ. The principal modifications may be most conveniently studied under the heads of—1. *herbaceous*, and 2. *woody* stems.

Herbaceous stems, or such as do not become woody, but die down to the ground in winter, are produced by annual and biennial plants, and in each successive flowering axis of herbaceous perennials; to these also are analogous the yearling shoots of arborescent plants. Taken by themselves, they are either *annual* or *biennial*; that is to say, they bear on the same axis green leaves belonging either only to one or to two seasons of growth. Annual herbaceous stems alone, of course, occur on true annual plants: they are produced also by those perennial herbaceous plants which send up a flowering stem from beneath the soil in spring; and with these are to be included most plants forming bulbs and corms.

In ordinary annuals the plumule or terminal bud of the seed shoots up at once into a more or less branched flowering stem, and the entire plant dies away after the seeds are perfected in autumn. Examples of this form may be seen in the Sweet Pea, *Veronica hederæfolia* (fig. 13), &c. In many perennial herbaceous plants forming rhizomes, and in most bulbous plants, a subterraneous bud shoots up in the early part of each season of growth, bearing green leaves and forming a flowering stem (fig. 23, *b*); in the autumn the whole of these structures disappear (*c*, *d*), while resting buds (*a*) are formed in the axils of the lower leaves beneath the soil, to repeat the growth in the following season. We have examples of this kind of stem in the Solomon's Seal, Garden Pæony, Aconite, Asparagus, &c. The young fleshy shoot with rudimentary leaves which these plants form in early spring is sometimes called a *turio* (this is exemplified in the edible part of the Asparagus). The leafy flowering stems of bulbs and tubers, such as those of the Lily, Potato, *Orchis*, &c., furnish further examples of the annual herbaceous stem.

Biennial herbaceous stems are found in true biennials and many herbaceous perennials. They are distinguished by the lower part of the axis producing green leaves in one season, and the upper portion growing into a flowering stem in the following year. Generally speaking, the internodes are little developed in the growth of the first season, and the leaves are often larger as well as more crowded; they also frequently die away early in the second season.

Examples of the biennial herbaceous stem are o be found in such true biennial plants as the Turnip, the Thistle, Parsley, &c. Here, when the seed is sown, it produces a stem with scarcely developed internodes, supporting a number of leaves which form a kind of tuft or rosette upon the ground; this growth remains almost at rest during the winter, and in the succeeding spring the terminal bud shoots up into a flowering stem. Sometimes several axillary buds also grow up into flowering stems, giving rise to the condition called "*radix multiceps*:" this may occur either in biennials or perennials. A similar kind of stem is found in such perennial herbaceous plants as the common Daisy, the Dandelion, &c.,

where axillary buds are produced at the base of the dying flowering stem in autumn, and grow up above ground at once to form leafy tufts, lasting through the winter, and giving birth to flowering stems in the next season.

Offsets, Runners, etc.—The leafy shoots of perennial plants, with their axis and adventitious roots, may be separated artificially, and used for propagating the plant (gardeners call this "parting the roots"); and certain plants are naturally multiplied in the same way, by buds or branches which have received special names. Thus the herbaceous flowering stems of the House-leeks (*Sempervivum*), after flowering, produce buds in the axils of their lower leaves which expand into leafy rosettes. The parent stem dying down, these are thrown off as detached plants, and strike root; in the following season they send up a flowering stalk and repeat the process. The separating tuft formed in the autumn is called an *offset* or *stolon*. The Strawberry-plant in like manner produces, in the axils of its leaves, buds which in the same season expand several of their internodes, and form long filiform branches, the buds of which give rise to rosettes of leaves, and strike root, and

Fig. 26.

Strawberry-plant with runners.

thus form independent plants: such shoots are called *runners* (fig. 26). In all these cases the herbaceous flowering stem is of two years' growth, its branching portion belonging to the autumn, the ascending flowering portion to the succeeding spring or summer.

Special names have been given to certain forms of the herbaceous stems, some of which are not very definite. Botanists sometimes call the stem of Grasses a *culm*.

Woody Stem. Buds.—The stem characteristic of arborescent plants presents itself in two principal classes of form:—one, where it is branched, constituting a *trunk* (*truncus*); the other, where it is an unbranched column, bearing its foliage as a terminal crown, forming what is sometimes called a *stock* (*caudex*).

These differences depend upon the number, position, and mode of development of the buds, only a few of which, in most cases, lengthen into shoots, the others becoming arrested in their growth. When, as in Dicotyledonous trees generally, *axillary buds*, or those formed on the side of the stem in the *axils*, or point of junction of the leaf with the stem, are developed into branches, we find a ramified trunk; when the terminal bud alone unfolds, as in most Palms, the globular and columnar Cactaceæ, and the Cycadaceæ, a simple columnar caudex is formed.

It is evident from this, that the mode of branching of a stem must be essentially dependent on the arrangement of leaves; but a complication arises from the frequent suppression or non-development of the axillary buds, often according to a regular plan; and, in fact, it is very seldom that all the axillary buds of a stem are developed (figs. 27 & 28).

Fig. 27.

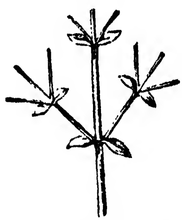


Fig. 28.

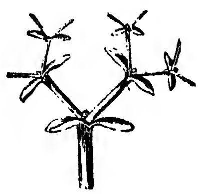


Fig. 27. Plan of indefinite ramification, with development of terminal and axillary shoots.
Fig. 28. Plan of definite ramification, with arrest of the terminal and development of the axillary buds, producing bifurcation.

This abortion of axillary buds is most extensively displayed in Monocotyledons; for the frequent existence of dormant buds in the leaf-axils, even of Palms, is shown not only by the occasional production of isolated lateral shoots, but by the frequent, and in some cases constant, development of buds in the axils of the basilar leaves, forming suckers round the base of the stem. A similar phenomenon occurs in the propagation of *bulbs*, &c.

Among Dicotyledonous plants, the influence of the suppression of buds in regular order is very great. In the Labiatæ we have opposite leaves; and as pairs of axillary buds are developed, the ramification is generally very symmetrical; in some of the *Caryophyllaceæ* with similarly *decussate* opposite leaves, one axillary bud only is developed, and the other is suppressed at each node, so that the branches, arising one by one, stand spirally arranged upon the stem. In the Firs, the branches often appear to arise in whorls, owing to the periodical development of a number of buds in the axils of closely succeeding spirally arranged leaves, with long intervals of total abortion.

Some trees grow year after year from the terminal bud, which closes up into a winter-bud in autumn (fig. 30). In the Elm &c. the terminal bud is not developed in the autumn, and the axillary bud next below continues the growth. In the Horse-chestnut the terminal bud of the annual shoot resolves itself into an inflorescence, and the growth of the next year depends upon the axillary buds; the same is the case in the Lilac (*Syringa vulgaris*) (fig. 29), in which, however, in this country, the terminal bud is generally abortive or suppressed, and the pair of axillary buds next below produce blossom, causing still more marked bifurcation of the branches.

Fig. 29.

Fig. 30.

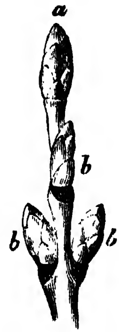


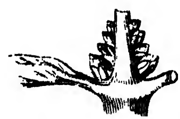
Fig. 29. Shoot of the Lilac, destroyed down to the first pair of axillary buds.

Fig. 30. A shoot, with a terminal (*a*) and solitary axillary buds (*b*, *b*, *b*).

As a general rule, of course, the frequent suppression or conversion into blossom of terminal buds tends to produce a bushy mode of growth, and *vice versâ*. In addition to this, the relative *force* of development of terminal and axillary buds is very important in determining general form, as we see in comparing the Black Poplar with its common tall variety the Lombardy Poplar, or Coniferous trees generally with deciduous trees. Even among the individuals of the same species we observe great differences in this respect, dependent on external conditions; for both Dicotyledonous trees and Conifers differ much in the relative proportion of main trunk and branches, when grown in close plantations, or standing in open situations.

Ordinarily, only one bud exists in an axil (fig. 30, *b*); but frequent exceptions to this occur, as in some species of Maple, in Honeysuckles (fig. 31), and in the Walnut. However, one of these is generally much larger than the rest, and is called the *principal* bud, while the others are *accessory*.

Fig. 31.



Numerous axillary buds of *Lonicera*.

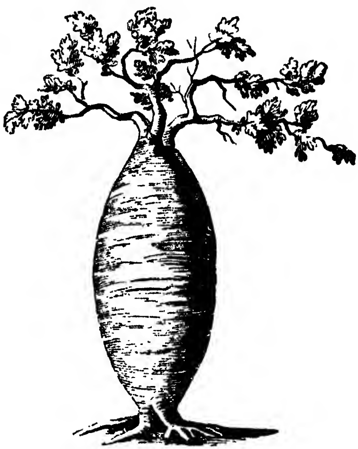
In some plants, as in many Solanaceæ, the buds occur in an irregular position, arising from the stem at a little distance above the leaf-axils. This is supposed to be due to the adhesion of the bud with the stem, and its uplifting with the latter as it lengthens.

The *Trunk* of arborescent plants arises as an herbaceous stem from the seedling, but usually becomes more or less woody before the close of the first season; in the autumn it ceases to develop internodes at its point, and the terminal bud closes up into a resting winter-bud enclosed in leaf-scales; buds of the same sort are produced in the axils of the leaves; and all or part of them open in the following spring, to produce a second generation of axes in the form of *shoots*; the same process being indefinitely repeated, a branched trunk is produced. If the central stem is not much

elongated, and the lateral ramifications are numerous, the result is a shrubby plant; if the growth of the main trunk predominates for a long time, but ultimately slackens, and the side branches grow more, the form seen in ordinary trees appears, where the top of the tree is more or less globose, as in what are called "round-headed" trees, like the elm; while if the growth of the central stem by the terminal bud is predominant throughout life, we have tall straight trunks with comparatively small ascending branches, such as are seen in the Lombardy Poplar, which is an instance of a *fastigiate* tree.

The originally cylindrical form of trunks often undergoes considerable alteration with age, depending upon peculiar modes of development of the woody structure within. Irregular prominences occur commonly on such old timber-trees as have large branches, greater enlargement taking place in the line between the base of the branches and the roots; this is often seen on old Oaks. Some tropical trees produce vast buttress-like projections in the same way. The forms of the trunk of the woody climbing plants of tropical forests present very remarkable irregularities, arising either from a twining habit, or from irregular development caused from lateral pressure or otherwise. In some kinds of *Bombax* (fig. 32), and in *Delabechea* (Bombaceæ), the trunk is swollen out in the shape of a great flask between the root and the main branches.

Fig. 32.



Trunk of a Brazilian *Bombax*.

The *Stock* or *caudex* is an undivided woody trunk, produced by the annual unfolding of a single terminal bud. Its internodes are commonly little developed, so that its sides are marked with the scars of its fallen leaves; sometimes, however, the internodes are developed, and then the stock has a jointed appearance, from scars or actual articulations at the nodes. The stocks of the Cactaceæ are remarkable for their form and consistence (figs. 35–37); their lateral buds are developed into tufts of spines, which are the representatives of the leaves of undeveloped branches.

The stock of the Palms exhibits considerable variety of form. In the Cocoanut- (*Cocos*) and Date-palms the internodes are scarcely developed, and the scars of the leaf-stalks, arranged in spiral order, cover the sides. The same holds good of the stock of *Cycas* and its allies, of *Xanthorrhœa*, and other arborescent Monocotyledons, and also of the stock of the Tree-

ferns (fig. 34). In other cases an internode is more or less developed between each leaf, and the stem is marked by a succession of scars running nearly round the stem (fig. 33), as in *Mauritia* and *Astrocaryum vulgare*; in *Geonoma* and *Chamædorea* the internodes are developed and the nodes thickened, so as to appear externally somewhat like those of the stems of Grasses, but they are not really articulated nor hollow like the latter. The *caudex* of the Palms furnishing the common Cane (*Calamus*) is chiefly distinguished from the last by the slenderness and extreme length

Fig. 33.

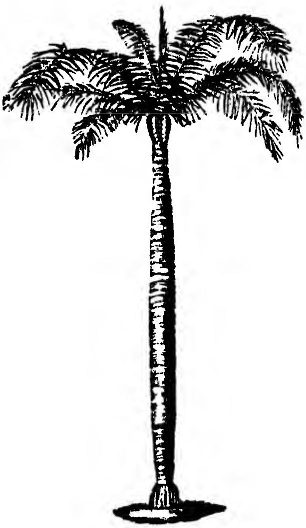


Fig. 34.

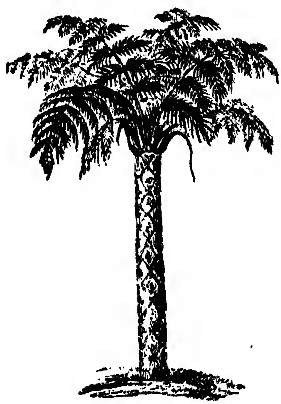


Fig. 33. Palm-tree (*Areca*) with unbranched caudex.
Fig. 34. An arborescent Fern with unbranched caudex.

of the internodes. Many of these Palm-stocks, which are simple in their principal mass, send out axillary buds at or below the ground, which form runners, and ultimately grow up independently of the parent. The aërial stocks of a few branch high above the ground, as in the Doum-palm and in *Pandanus* (fig. 10), where the terminal bud appears to undergo successive bifurcations, but really sends off at intervals single axillary buds, the development of which soon equals that of the parent axis, and causes the deflection of the latter so as to give a forked appearance. A similar mode of growth is observed in certain Hæmodoraceæ (arborescent Monocotyledons, natives of S. America), also in the Liliaceous genus *Yucca*. The stocks of some of the Cactaceæ are undivided, as in *Melocactus* (fig. 36), *Echinocactus*, and *Mamillaria*, &c.; but in others a few branches arise, giving a compound character, as in various species of *Cereus* (fig. 37) and in the leaf-like stalks of *Opuntia* (fig. 35). Analogous structures occur in foreign species of *Euphorbia*.

Fig. 35. Fig. 36. Fig. 37.

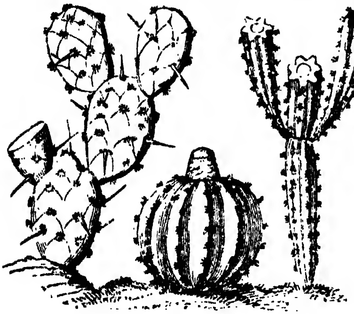


Fig. 38.

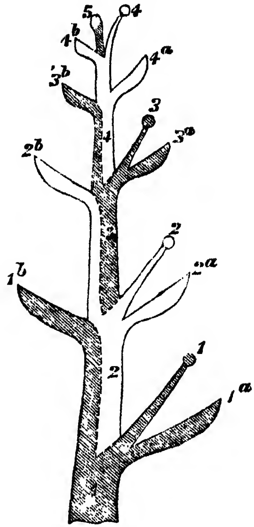


Fig. 35. Stem of *Opuntia*. Fig. 36. Stem of *Melocactus*.
Fig. 37. Cylindrical and ribbed stem of *Cereus*.
Fig. 38. Diagram to illustrate the nature of a sympode, the imperfect separation (so called adhesion) of leaves, and the uplifting of the latter with the growth of the shoot; the primary shoot ending in a terminal bud which is deflected to one side. 1 *a*, one of the leaves of the primary shoot 1, in its ordinary position. 1 *b*, another leaf of the same shoot adherent to or undetached from 2, the shoot produced in the axil of 1 *b*, and carried up with 2 in its upward growth. The shoot 2, 2, with its leaves 2 *a*, 2 *b*, grows in the same manner, and others succeed it. The portion of the main axis marked 1, 2, 3, 4, 5 in one vertical line is a sympode, being composed not of one continuous axis of one and the same generation, but of a series of axes of different and successive generations, ranged in vertical order.

Ramification.—The same general methods occur in the branching of roots, of stems, of leaves, and of inflorescences, and indeed are also met with in purely cellular plants, as in Algæ and Fungi. *Caulerpa*, though strictly unicellular, has mimic stem-branches, leaves, and roots. Growth takes place by means of growing points (*puncta vegetationis*), which will be more fully described under the head of Minute Anatomy, and which, in the case of stems, are enclosed within, and form the central terminal mass of the buds. The growing point is terminal or lateral, primary or secondary. If at the end of a shoot or branch it is *terminal* and *primary*, or of the *first degree*; if at the side of a shoot it is *lateral* and *secondary*, or of the *second degree*. In the latter case it is lateral because it is pushed out from the side of the primary shoot beneath its apex, and it is secondary because it is necessarily formed after the primary growing-point, and belongs to a subsequent generation. In like manner we may have in succession tertiary buds, or shoots of the third, fourth, fifth degree, and so on.

Monopodial branching.—By the growth of terminal buds or growing

points the stem is continuously lengthened in one direction; by the development of lateral ones from below upwards (acropetal) it becomes branched. This mode of growth is called *monopodial* (fig. 27).

Dichotomy.—In some instances (*e. g.* the tendrils of some vines, the roots of Lycopods, and frequently in Cryptogams) the terminal growing-point bifurcates. Each pair of new shoots so formed is then of the same degree or order, because each is formed from the same original growing-point and at the same time. The growing-point may, in this manner, divide into several divisions of the same generation or relative order. The shoots formed dichotomously, as above explained, are monopodial or *indefinite* as to their ramification, and may grow equally and regularly, or the growth may be arrested in certain of them, and hence may arise much difference in the appearance of the mode of branching.

Dichasium.—In the foregoing illustrations the terminal growing-point either continues to lengthen as growth goes on, or it divides into divisions of equal degree, though often of unequal vigour. But it very commonly happens that the terminal growing-point or bud ceases to grow after a time (figs. 28, 29). This may happen accidentally or from the effects of frost or other injury, however caused, or it may occur constantly and naturally, as in many trees, *e. g.* the Lilac (fig. 29). When arrest of growth in the terminal bud takes place in the manner just indicated the lateral buds often grow so vigorously, and are so closely placed, that they appear to radiate from the same point as if they were formed by dichotomy of the terminal growing-point. This false or apparent dichotomy is sometimes called a *dichasium* or false cyme (fig. 28).

Sympode.—When in the case of a dichotomous ramification one of the divisions grows more vigorously than the other, or, which amounts to the same thing, when one of them is arrested in its growth or altogether suppressed, then, although the two divisions are of equal degree and age, yet the stronger of the two presents the appearance of and grows in the same direction as the primary shoot, while the smaller one is often pushed on one side, so as to look like a lateral shoot of a subordinate degree (fig. 38). The appearance may thus be that of a continuous shoot formed by the extension of one growing-point and giving off lateral branches; but in reality the shoot is not the result of the extension or bifurcation of one growing-point, but of a number of growing-points of different generations formed in succession one after the other. In this way what is called a *sympode* is produced, and ramification so characterized is sympodial. This arrest of growth may take place regularly or irregularly, producing corresponding variations in the form of the ramifications: thus, supposing a branch to divide into a number of subdivisions by repeated bifurcations to the right hand or to the left respectively, it may happen that all the shoots on the one side are arrested in their growth as compared with those on the other. Or it may happen that the arrest of growth may take place first on one side and then on the other in regular alternate order. All these modifications may be seen in the mode of branching in various cellular Cryptogams as well as in higher plants.

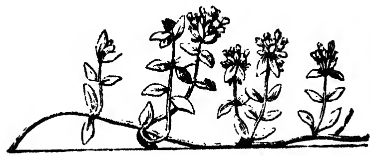
Characters of the Stem and Branches.—In the description of stems and branches generally, certain technical terms are in use, in addition to those above explained. These refer principally to—a. *consistence*; b. *direc-*

tion and habit of growth; c. *form*; d. *condition of surface*; e. *ramification*; and f. *dimensions*.

a. *Consistence*.—The terms *herbaceous* (*herbaceus*) and *woody* (*lignosus*) need no further definition. Some stems are *fleshy* or *succulent* (*carnosus*), as in *Cactus*, &c. Most stems are *solid* (*solidus*); those of the majority of Grasses and the Umbelliferæ (Carrot, Celery, &c.) and the Horsetails (*Equisetum*) are *hollow* or *tubular* (*fistulosus*).

b. *Direction*.—Stems may be truly *erect* (*strictus*), *flexuous* (*flexuosus*) or *nodding* (*nutans*, *cernuus*). Stems which turn upwards from a horizontal base are called *ascending* (*ascendens*); those lying along the ground without rooting are *procumbent* or *prostrate* (*decumbens*, *procumbens*, *humifusus*) (fig. 39); if a prostrate stem roots at its nodes, it becomes *creeping* (*repens*). Slender stems neither lying on the ground nor creeping may be *pendent* (*pendulous*) when growing on rocks &c., and *floating* (*fluitans*) when growing in water. Weak stems also rise from the ground as *climbing* (*scandens*) or *twining* (*volubilis*) stems.

Fig. 39.



Procumbent stem of Thyme.

Climbing stems support themselves in various ways:—the Ivy by tufts of adventitious roots, which attach themselves firmly to foreign bodies; the climbing species of *Clematis* and the Canary-creeper (*Tropæolum peregrinum*) by hooking their leaf-stalks round the support; other plants by *tendrils*, as the Vine, Peas, Cucurbitaceæ, &c.

Twining stems coil themselves spirally round the supporting body, turning sometimes in one direction, sometimes in the other, as in the Hop, Convolvulus, *Cuscuta*, &c. If the direction from below is from the left upwards to the right hand of the observer, supposed to be standing in the position of the body around which the coil winds, the coil is said to be *dextrorse*, if in the opposite direction *sinistrorse*; but by some writers the observer is supposed to stand in front of the coil, and then the application tf the terms is reversed. Some of the tropical twiners produce woody orunks resembling large cables.

c. *Form*.—The principal variations in form are designated by terms requiring no explanation, such as *cylindrical* or *terete*, *conical*, *columnar*, &c. If a stem presents thickenings opposite the origin of the leaves (nodes), it is called *knotted* (*nodosus*); the reverse condition, when there are constrictions at intervals, is called *jointed* (*articulatus*). Other terms refer to the shape as displayed in a cross section of the stem. A stem is terete (*teres*) when it presents a circular section; *compressed* (*compressus*) when the section is elliptical; *angular* when the section is polygonal, under which head are distinguished, in a three-angled stem for example, *trique-*

Fig. 40. Fig. 41. Fig. 42.

Fig. 40. A triquetrous stem.
Fig. 41. A quadrilateral or square stem.
Fig. 42. A ribbed stem.

trous if the three angles are sharp (fig. 40), *triangular* if they are about right angles, and *trigonous* when the angles are obtuse or rounded off. When the surface presents a great number of longitudinal ridges, it is called *ribbed* (fig. 42); numerous longitudinal grooves render it *furrowed* (*sulcatus*). In some cases the projecting angles of stems are *winged* (*alatus*), as in many Thistles; in other cases the stem or branch is flattened, so as to resemble a leaf, in which case the term *cladode* is applied, as in *Ruscus* (fig. 43). Such leaf-like branches or *cladodes* are distinguishable from true leaves by their axillary position, mode of origin, internal structure, and by the circumstance that they bear flowers.

Fig. 43.

Foliaceous cladodes of *Ruscus aculeatus.*

The *apex* of a stem or branch is usually pointed or conical, but it may be globose or concave, as in the flower-stalk of a Rose.

d. The *surface* of a stem may be *smooth* (*lævis*) or *striate* (*striatus*), *i. e.* marked with fine grooves and ridges. It may be devoid of epidermal appendages or *glabrous* (*glaber*), or furnished with a more or less dense coat of hairs, bristles (*setosus*), or thorns (*spinosus*). Similar terms are still more commonly applied to the surfaces of *leaves*.

e. *Ramification.*—A stem is either *simple* or *branched*; if the ramification is excessive, it is called *much-branched* (*ramosissimus*). The branches may be *erect*, *spreading* (*patens*), *outstretched* (*divaricatus*), *deflexed* (*deflexus*), or *pendulous* (*pendulus*). These qualities especially affect the crown or head of trees.

f. *Dimensions.*—Different terms are applied to plants with woody stems, according to their size and mode of branching. A *tree* (*arbor*) is a plant with a woody trunk and branched head. A *shrub* or *bush* (*frutex*) is a kind of dwarf tree, where the main trunk is little developed, but the lateral branches very much so. *Under-shrub* (*fruticulus*) is the diminutive of this.

Sect. 4. The Leaf.

Leaves are the lateral organs issuing from the ascending portion of the stem and its branches *below their growing points*, and in general are flat, expanded plates, produced directly from the superficial part of the stem, and from which, after a certain term of existence, they are removed, either by breaking off at a distinct joint, or by decay.

The simplest leaves occur as flat plates traversed by a nerve, as in Mosses. In many Algæ and cellular Cryptogams processes of the thallus may be seen resembling leaves in form and arrangement, but not in structure. The term *phyllome* is used in a comprehensive sense to signify any leaf, or modification of a leaf, springing from a *caulome* or axis. In some cases, as in Cactus (figs. 35–37), the true leaves are absent, their office being filled by the green stem. Normal leaves, belonging to the vegetative system, are alone taken into account in this chapter; the modified foliar organs composing flowers must be treated separately.

The leaves arise from and mark the *nodes* of the stem; and it has been already stated that it is at the nodes, in the *axils* of leaves, that lateral or axillary buds are as a general rule produced. From this it follows that the *arrangement* of the leaves must be of great importance, not only in reference to their own relative positions, but as determining more or less completely the plans of ramification of stems. It is found that the modes of arrangement of leaves are in accordance with certain general laws; and a particular study of these laws has been pursued, under the name of

Phyllotaxis.—Leaves exhibit two principal types of arrangement: either they are solitary, one only occurring at a node, or two or more spring from the stem at the same level. When the leaves stand alone, they are said to be *alternate* or *scattered* (fig. 44); where two stand at the same level, facing one another, they are called *opposite* (fig. 45); and if more than two originate at one level, forming a circle, the leaves are called *whorled* or *verticillate*. Very rarely two leaves appear to spring from the same node, as in what are called *geminate* leaves (*Solanum*). This condition is supposed to arise from irregular displacement and partial adherence of one of the leaves to the stem, or from division of one leaf into two.

Fig. 44.

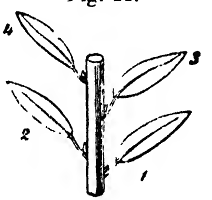


Fig. 45.

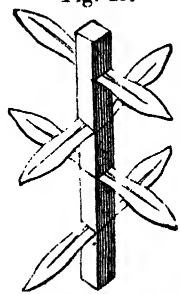


Fig. 44. Diagram of the arrangement of alternate distichous leaves.
Fig. 45. Diagram of the arrangement of decussate opposite and tetrastichous leaves.

Really whorled leaves are not so common as is sometimes imagined, the whorled condition being imitated in some cases, as in many Stellatæ, by an excessive development of interfoliar stipules; truly whorled leaves are seen in *Paris* and *Myriophyllum*. Representatives of the two principal types are found in the embryo of Monocotyledons and Dicotyledons—the former having a solitary *cotyledon*, the latter having two, placed the one opposite to the other (fig. 3); but this opposite arrangement of the cotyledons is not always associated with a like disposition of the true leaves.

Alternate leaves exhibit many modifications of arrangement. Sometimes they are truly alternate; that is, the second leaf is exactly on the opposite side of the stem from the first, and the third exactly over the first: a series of leaves arranged in this way

form two perpendicular rows. Such leaves are termed *distichous* or *two-ranked* (fig. 44); examples of which are found in the Grasses.

If the second leaf is not opposite to the first, but at a point distant from it one third of the circumference of the stem, and the third leaf one third further round, the fourth leaf, likewise distant one third from the preceding, will stand over the first. Leaves so arranged form three perpendicular rows, constituting the *tristichous* or *three-ranked* arrangement, which is common among the Monocotyledons (fig. 46).

Now when a line is drawn round the stem so as to pass regularly from leaf to leaf, we find that its course is *spiral*. In the *distichous* case the spiral line starting from any given leaf completes one circuit and then commences a new one at the third leaf; in the *tristichous* arrangement the spiral completes one circuit and begins a new one with the fourth leaf (fig. 46). The series of leaves included by the spiral line in passing from the first leaf to that which stands directly above it is called a *cycle* (fig. 47); the fraction of the circumference of the stem which measures the angular distance between any two succeeding leaves in a cycle when projected on a plane is termed the *angular divergence*. In

Fig. 46.

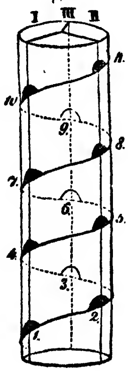


Fig. 47.

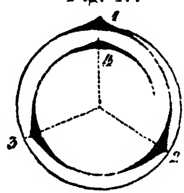


Fig. 49.

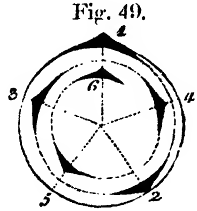


Fig. 48.

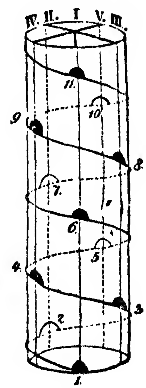


Fig. 46. Projection of the $\frac{1}{3}$ arrangement.
Fig. 47. Horizontal projection of a cycle of the $\frac{1}{3}$ arrangement.
Fig. 48. Projection of the $\frac{2}{5}$ arrangement.
Fig. 49. Horizontal projection of a cycle of the $\frac{2}{5}$ arrangement.

the distichous, represented by the fraction $\frac{1}{2}$, it is one half of 360°, or 180°; in the tristichous, or $\frac{1}{3}$, it is 120°.

These fractions not only represent the angular divergence, but

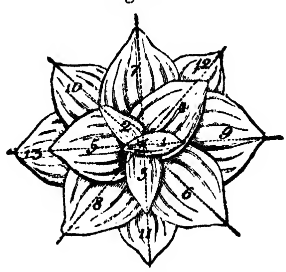
also the entire character of the arrangement; for the numerator, as is seen, indicates the number of turns of the spiral forming a cycle, while the denominator expresses the number of leaves in that cycle.

In the *pentastichous*, *quincuncial*, or *five-ranked* arrangement the sixth leaf stands over the first (figs. 48 & 49), commencing a second cycle; but the spiral line passing through the first five leaves makes *two* circuits round the stem; moreover the successive leaves stand at a distance from each other of two fifths of the circumference of the stem, or 144°; while the expression of the angular divergence, $\frac{2}{5}$, indicates also the number of turns round the stem in the cycle, and the number of leaves in the cycle, as before.

The next degree of complexity of the arrangement is where eight perpendicular rows of leaves exist, and the ninth leaf is over the first. In this case the spiral takes *three* turns in completing the cycle; and the expression $\frac{3}{8}$ indicates three eighths of the circumference, or 135°, the angular divergence of the successive leaves.

When we place the foregoing figures together, thus: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, it will be observed that each fraction has its numerator composed of the sum of the numerators of the two preceding fractions, and its denominator of the sum of the two preceding denominators; and it is really found that all higher complications, in normal conditions of stems, exhibit some further indication of the same ratio, and are marked successively by $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, $\frac{21}{55}$, &c.*

Fig. 50.



Rosette of leaves of *Plantago media*, seen from above; the leaves on the $\frac{5}{13}$ type.

The simpler forms of arrangement are the most common; those marked by higher fractions are chiefly found in plants with the leaves much crowded, as in the House-leek. The scales of the cones of Pines and Firs offer good examples of these spiral arrangements. The following examples may be mentioned for observation:—

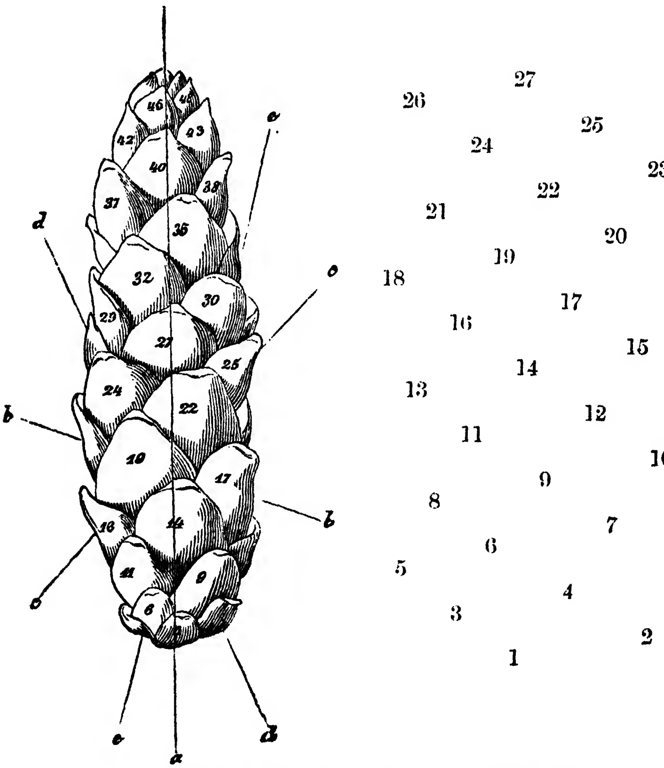
Plan $\frac{1}{2}$. Leaves of Grasses, *Vanda*, *Iris*, *Gladiolus*, Elm, Lime, &c.

* [The mathematician will observe that these fractions are the *successive convergents of the continued fraction* $\frac{1}{2+}\frac{1}{1+}\frac{1}{1}$ &c., and that any leaf being taken as No. 1, the second must lie between 120° and 180° from it. Its position, corresponding successively to each of the above series of fractions, oscillates alternately on either side of a point indicated by the limiting value of the continued fraction, viz. 137° 30′ 28″+.—G. H.]

Plan $\frac{1}{3}$. Leaves of Sedges (*Carex, Scirpus*), Tulip, Alder, Birch, &c.
Plan $\frac{2}{5}$. Leaves of Apple, Cherry, Poplar, Oak, Walnut, &c.
Plan $\frac{3}{8}$. Leaves of Flax, Plantain (*Plantago*) (fig. 50), Holly, Aconite, &c.
Plan $\frac{5}{13}$. Eyes (buds) of Potato-tubers, cones of *Pinus Strobus* (fig. 51).
Plan $\frac{8}{21}$. Cones of Spruce-fir (*Abies excelsa*).

When the leaves are very numerous and much crowded, it is often difficult to trace the *fundamental spiral*, as the vertical ranks are not

Fig. 51.



Cones of *Pinus Strobus*, with the scales in the $\frac{5}{13}$ arrangement.

evident. In these cases the arrangement is ascertained by studying the *secondary* spirals which appear. These are more or less numerous, according as the fractional expression of the fundamental spiral is higher.

For example, in examining the cone of the White Pine, a complex spira arrangement is at once recognized, which will be understood by

reference to the adjoining diagram (fig. 51). Assume any scale as No. 1. Select the scale over it, in as nearly a vertical line as possible, such as that numbered 14 in fig. 51. Secondary spirals parallel to each other will be seen running to the right and to the left hand. Such are indicated by the numbers 1, 6, 11, 16, &c. to the left, and by 1, 9, 17, &c. to the right of the reader. Or, again, very *depressed* spirals are formed by the scales marked 9, 11, 13 (not seen) to the left, and by 6, 9, 12 (not seen) to the right. Of all such spirals, select *the two most elevated*, which pass by and overlap the scale immediately over that chosen as No. 1. These will be the spirals indicated by the numbers 1, 6, 11, 16, &c. to the left of No. 14, and by 1, 9, 17, 25, &c. passing to the right hand of that scale. Count the number of secondary spirals parallel to these two respectively. There will be found to be *eight* such parallel spirals in all sweeping round to the right; and *five*, such as 1, 6, 11, 16, &c., to the left. Take the lowest of these two numbers, or 5, as the numerator, their sum, 5+8, or 13, as the denominator, and $\frac{5}{13}$ will be the fraction required.

To *prove* this, numbers must be assigned to every scale of at least the first cycle, *i. e.* those included between No. 1 and that numbered 14 in the figure.

Starting with the scale assumed as No. 1, add 8 (that is, the number of parallel spirals to the right) to 1, and write 9 on the next scale, as in fig. 51. Add 8 again, and write 17 on the next, and so on.

Again, add 5 to 1, and write 6 on the adjacent scale on the left-hand spiral; add 5 to 6, and write 11 on the next, and so on.

Two entire secondary spirals intersecting at No. 1 will thus be numbered.

To number any other scales, we may start from either of these spirals, always adding 5 to the number of any scale on going from right to left, and 8 on going from left to right: thus,

$$6+8=14. \quad 14+8=22,$$
$$\text{or, } 9+5=14. \quad 17+5=22.$$

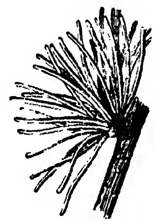
So that we can assign by either method the numbers 14 and 22 to the proper scales. Similarly all the scales of the cone can be numbered. Only those of a lower number than 6 and 9 are obtained by *subtraction* of 8 and 5. Now, it will be seen that 14 will be the number of the scale directly over No. 1. This *proves* that the denominator is correct, for there will be 13 scales in the cycle.

Secondly, having, we will assume, numbered all the scales of the cycle between Nos. 1 and 14, if the cone be held erect, and is made to revolve while the eye passes from No. 1 to No. 2, then on to No. 3, &c., up to No. 14, the observer will find that he revolves the cone *exactly five times.* In other words, a spiral line passing through the scales 1, 2, 3, 4 . . . up to 14, which constitutes one cycle, will coil five times round the axis.

The perpendicular distance between the points of origin of successive leaves is dependent simply on the degree of development of the internodes of the stem. These may be so short that, as in the common Stone-crop (*Sedum acre*), *Araucaria imbricata*, &c.,

the leaves overlap more or less along the developed axis; such leaves are termed *imbricate*; and this condition is very common in the leaf-scale forms of the leaf. A great number of well-developed leaves are often crowded together by the non-development of internodes at the base of the flowering stems of perennial herbs, such as the various Saxifrages, the Turnip, Dandelion, &c.; and where these so-called "radical" leaves are arranged with some regularity, and spread out horizontally as in the House-leeks, they are said to be tufted, *cæspitose* or *rosulate* (fig. 50).

Fig. 52.



Fasciculate leaves of the Larch.

A somewhat similar condition occurs upon branches of some trees, on which a number of leaves appear to spring from one point, as in the Larch (fig. 52) and the Berberry; the collections of *fasciculate* leaves really belong to a branch the internodes of which are not developed, so that they all spring at once from the leaf-axil in which the branch-bud was formed.

In other Conifers the number of leaves in these bundles is smaller and very regular and characteristic; *e. g.*, in *Pinus sylvestris* two leaves are thus associated, in *P. Cembra* three, in *P. Strobus* five, &c. In those buds of the Larch which afterwards unfold into shoots, the transition from a *fasciculate* into a regular spiral arrangement becomes evident.

Opposite and whorled leaves likewise exhibit great regularity. The number of leaves in a whorl is here also sometimes expressed by a fraction, which is enclosed in a parenthesis; the denominator in this case indicates the number of leaves in one circle.

Fig. 53.

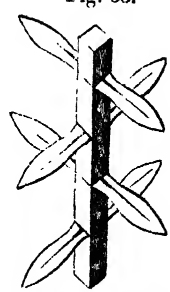


Diagram of decussating pairs of leaves.

Examples of those in true leaves are furnished by the following plants:—

($\frac{1}{2}$) plan (opposite leaves). Pinks, Labiatæ.
($\frac{1}{3}$) „ *Lysimachia vulgaris, Trillium.*
($\frac{1}{4}$) „ *Paris quadrifolia.*
($\frac{1}{5}$) „ *Myriophyllum pectinatum.*

Sometimes the numbers vary on different parts of the same stem, as in *Hippuris*.

When leaves are opposite, the pairs are almost invariably alternate *; that is, they cross at right angles, the third pair standing over the first. Such leaves are called *decussate* (fig. 53). With whorls of three leaves,

* An exception is seen in *Potamogeton*.

again, we usually find a similar alternation; the leaves of the second whorl stand over the intervals between those of the first, the leaves of the third whorl standing over the leaves of the first.

[There is reason to believe that the arrangement of alternate leaves has resulted from the development of the internodes between opposite leaves; for when the latter occur at the base of a stem and alternate leaves above, it will be found that, as the internodes are gradually developed, the leaves always appear in succession in a spiral order; and most frequently the sixth falls over the first, that being the *last* out of three pairs of decussating leaves; or else the ninth falls over the first, that being the *first* leaf of the fifth pair. The leaves on becoming alternate soon cease to be decussating, and gradually acquire their proper angular divergence. Moreover, as decussating pairs of leaves can give rise to the ordinary series of fractions, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, so alternating whorls of "threes" give rise to the series $\frac{2}{7}$, $\frac{3}{11}$, $\frac{5}{18}$. Both kinds can be well studied in the Jerusalem Artichoke.—G. H.]

```
           2
           .
           5
   3 . 8       7 . 4
           9
           .
           6
           .
           1
```

Diagram illustrating the order of development of leaves when the internodes are beginning to be formed, and before the proper angular divergences exist.

Conversely, if the internodes between the component leaves of any individual spiral cycle were undeveloped, while those between *successive* cycles were lengthened, a verticillate arrangement would result. In certain plants (for example, the Myrtle, the Antirrhinum) alternate and opposite leaves occur on the same stem. This is the case also in those Dicotyledons where the true leaves succeeding the opposite cotyledons are alternate, as in the Scarlet Bean, Mustard, &c.

It is requisite to distinguish between *simultaneous whorls*, where the parts composing it are developed simultaneously, and *successive* whorls, where the parts are developed successively, but are brought together by the non-development of the internodes. The arrangement of the leaves in the manner above indicated is to a great extent connected with the deposition of the fibro-vascular bundles of the stem. It should, however, be stated that the arrangement of the leaves on the stem is not always the same as that on the branches.

Certain terms are in common use in descriptive works to indicate the absolute position of the leaves upon the stem. The name *radical* leaves is applied to those, usually of larger size than the

rest, which are often found collected at the base of flowering stems of herbaceous plants, such as the Dandelion, Lettuce, Turnip, *Plantago* (fig. 11, p. 21), &c. The ordinary leaves of the stem are sometimes distinguished as *cauline* or *stem-leaves*, while the term *ramal* is occasionally used for those on the shoots of trees and shrubs when these present special characters.

The leaves belonging to the inflorescence are called bracts. Their phyllotaxis generally agrees with that of the stem-leaves.

The point whence a leaf springs from the stem is commonly called the *insertion*. Leaves are either *articulated* there, separating when dead by a distinctly characterized line of fracture, or they merely wither down, and leave their bases as a ragged covering to the stem; the latter condition occurs mostly in leaves with sheathing bases.

A perfect leaf is divisible into two regions (fig. 54)—the *blade* or *lamina* (*b*), and the *leaf-stalk* or *petiole* (*c*); the latter, when present, may be more or less completely represented by a *sheath* or *vagina* (*a*), partly or wholly embracing the stem from which it arises. At the base of the petiole often occur distinct leaf-like appendages, called *stipules*. All parts of the leaf—blade, stalk, and stipules—are much subject to modification, and may even exist in the forms of *tendrils*, *spines*, *pitcher-like* organs, &c., very unlike

Fig. 54.

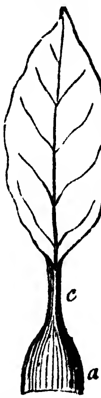
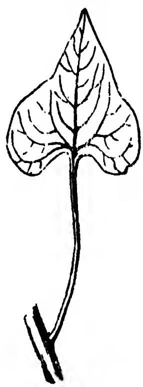


Diagram of the regions of a leaf: *a*, sheath; *b*, blade; *c*, stalk.

Fig. 55.



A stalked simple leaf equally cordate at the base.

regular leaves. These metamorphosed leaves, or parts of leaves, are best treated of separately.

The stalk-like petiole (fig. 55), most common in Dicotyledons, always has the base slightly widened out at its point of emergence from the stem; in the leaves of Palms, the Banana, Scitamineæ, &c. the base is expanded so as to embrace the stem, while in the Grasses the petiole is entirely represented by a sheath (fig. 59). The green part of the leaves of the Hyacinth and other bulbous plants is the blade, and will be found continuous below with a colourless, fleshy, petiolar portion, forming one of the "coats" or sheaths of the bulb (fig. 17, p. 25).

The leaf may, however, be represented by one only of the regions. It is very common to find leaves without distinct petioles, the blade springing directly from the stem: such leaves are called *sessile* (fig. 56). On the other hand, the petiolar region may exist without the blade; and among the cases of this sort a considerable variety of conditions is met with. Petiolar structures, devoid of laminæ, and more or less reduced to scales or membranous sheaths, are commonly found on subteranneous stem-structures, such as bulbs, rhizomes, &c., whence we have denominated this part of the stem the "leaf-scale region." Similar scales appear in place of green leaves in the "true-leaf" region of various parasitic plants, such as *Orobanche*, in which the leaves have no physiological function to perform; and they recur periodically on the stems of arborescent plants which form winter buds, in the shape of bud-scales. In the true-leaf region the blade is either supported on a stalk-like or sheathing petiole, or is sessile. The sessile con-

Fig. 57.

Fig. 56.

Fig. 58.

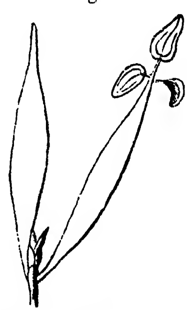


Fig. 56. A sessile leaf. Fig. 57. Phyllodium of an Acacia.
Fig. 58. Two phyllodia of *Oxalis latipes*, one with a ternate blade.

dition is generally more common toward the upper part of stems and shoots; and in the *bracts* or leaves belonging to the inflorescence the petiolar region is comparatively seldom developed. The

first leaf (*Vorblatt* of the Germans) on a branch in many Monocotyledons is of a different form from the rest, and is found in the angle between the branch and the stem from which it springs. In Dicotyledons there are often two such leaves at the base of a branch, right and left, and occasionally they are united into a tube. They are sometimes formed after the other leaves according to Hofmeister.

In some families the true-leaf region is clothed with petioles expanded into the form of laminæ; these are called *phyllodes* (figs. 57 and 58), and in such cases the true laminar region is often partially or entirely suppressed.

The transition from the petiolar leaf-scale organs into perfect leaves with sheathing petioles may be observed not only in bulbs, but in many Grasses with creeping stems, which exhibit, at the junction of the leaf-scale and true-leaf regions, sheaths surmounted by short green lancet-shaped laminæ, increasing in length in successive leaves.

Stipules.—When the petiole appears as a distinct leaf-stalk, it is often accompanied by a pair of more or less distinct foliaceous appendages at its base, called *stipules*. When these exist, the leaf is called *stipulate* (fig. 63); when they are absent, *exstipulate*.

The presence or absence of stipules is often a very constant character of Natural Orders. The various forms of stipulate petioles form a kind of transition to the petioles with sheathing bases.

Petiole.—The *pĕtiole* is usually of semicylindrical form, with the flat surface above; not unfrequently this upper surface is channelled (*canaliculate*), giving a more or less crescentic section; in a few instances, especially in the Aspen, it is laterally compressed. Where it is cylindrical its structure is like that of a branch.

The stalk-like petiole is either *simple*, when it supports a single blade, or it is branched or *compound*, when the blade is composed of a number of distinct leaflets; the branches are sometimes called *partial petioles*, and may even be articulated at their points of origin from the primary petiole.

Compound petioles supporting the leaflets of compound leaves are known from branches, which at first sight they resemble, by arising independently from the stem, by having buds in their axils, and by the absence of any indication of a leaf immediately beneath them.

Phyllodes.—The flattened or leaf-like petiole, called a *phyllode*, resembles a lamina, but is known by standing edgewise on the stem—that is, with its flat faces parallel with the direction of the

stem; in some cases *phyllodes* exist without true laminæ (fig. 57), in others the laminæ are more or less developed at the summit (fig. 58).

Striking examples of *phyllodia* with or without laminæ are furnished by various species of *Acacia* (figs. 57 & 101), in many of which the blade is present, compound and bipinnate.

Vagina.—The sheathing portion or *vagina* is the only portion of the petiole which is developed in certain plants, as in the Grasses and Sedges (figs. 59–61), in which it forms a complete sheath to the stem, and passes at once into the blade at the top: this sheath is merely rolled round the stem in the Grasses; but its margins are not disunited, but form a tube, in the Sedges. The vaginal petiolar region is more or less distinctly evident in many Monocotyledonous leaves which at first sight appear to be sessile, as in the Tulip, Hyacinth, &c.; and it is generally more or less developed at the base where a distinct leaf-stalk exists in this class, as in the Palms and, above all, in the Musaceæ. In many Dicotyledons also the base of the petiole is enlarged into a sheath, as in Umbellifers (fig. 62).

Fig. 59.

Fig. 60.

Fig. 61.

Fig. 62.

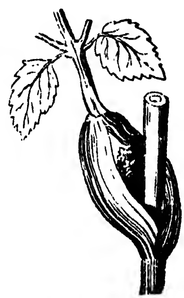


Fig. 59. Leaf-sheath of a Grass, with an entire *ligula*, *.
Fig. 60. Leaf-sheath of a Grass, with a bifid *ligula*, *.
Fig. 61. Leaf-sheath of *Eriophorum*.
Fig. 62. Sheathing base of the petiole of *Angelica*.

Sometimes the petiole is *winged* (*alate*), as when a narrow plate of the blade structure springs from its margins; in certain cases these wings are *decurrent* down (or, rather, are continuous with the sides of) the stem from which the leaf arises, as in many Thistles, *Verbascum*, &c., producing a *winged* or *alate* stem.

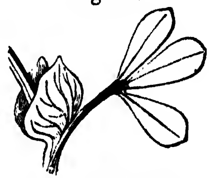
Cicatrix.—The petiole is ordinarily more or less distinctly jointed to the stem; and when the leaf falls, it leaves a more or less extensive well-defined scar upon the stem, called the *cicātrix*; in

woody Dicotyledons there is generally a little protuberance under the cicatrix, which is termed the *pulvīnus*. In Monocotyledons the cicatrix is usually very broad, from the base of the petiole embracing the stem widely. In some cases the petiole is not regularly disarticulated, but withers down; but then the decay generally terminates at a definite point a little above the base, leaving a portion of the latter in the form of a scale-like or tooth-like process projecting from the stem.

Tooth-like processes left by the decay of the petioles may be seen on the underground stem of the common Primrose &c., and on the trunks of certain Palms.

Stipules.—The *stĭpules* or leaf-like appendages of the petiole usually stand at the base of the petiole, one on each side, free or adherent to it (fig. 63). The *free* leafy stipules are sometimes highly developed, and in *Lathyrus Aphaca* they exercise the functions of the blade, the leaves of this plant consisting merely of a petiole destitute of a lamina. When the margins of the stipules next the petiole are continuous with that organ, forming as it were wings to it (*Rosa*), they are called *adnate* (fig. 64). They are also often united by their margins independently of the petiole, or, in other words, are not separated from each other (*connate*): thus in the Plane tree and in *Astragalus* they are united by the outer mar-

Fig. 63.

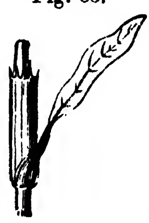


Leaf of *Lotus* with free stipules.

Fig. 64.

Compound (pinnate) leaf of the Rose, with adnate stipules.

Fig. 65.



Ocrea of *Polygonum*.

gins (turned away from the petiole) so as to form a kind of leaflet on the opposite side of the stem (*intrapetiolar*); in *Potamogeton*

they are united by their inner margins *above* the petiole, so as to form a compound *axillary* stipule; in the Polygonaceæ they are not only united on this side, but also by their outer margins on the other side of the stem, thus forming a short tubular sheath round the latter, called an *ocrea* (fig. 65). All the above cases relate to stipules of single leaves; but similar coherence or lack of disunion occurs in the stipules of opposite leaves, where it is not uncommon to find the two stipules which stand between the leaves, at back and front, more or less confluent into a single leaf-like or scale-like body (*interpetiolar stipule*), so as to form a kind of whorl with the true leaves.

This interpetiolar confluence of the stipules is very characteristic of the Order Rubiaceæ; and the apparent whorls of the *Stellatæ* (*Galium*, &c.) often exhibit a confluence of the highly developed leaf-like stipules.

At the summit of the sheath of the leaf of Grasses exists a little membranous scale, connecting the blade with the epidermis of the stem; it is either entire or forked at the top (figs. 59 * & 60 *); this structure, called the *ligule*, is a mere excrescence from the stalk.

The stipules of some plants fall off at an early period. This is the case with the interpetiolar stipules of various Rubiaceous plants. It also occurs commonly when the stipules form the outermost envelopes of the leaf-buds, as in Magnoliaceæ, *Ficus elastica*, the Beech tree, &c.

Small secondary stipules exist at the base of the partial petioles of some compound leaves, especially of Leguminosæ (*Desmodium*); they are called stipels (*stipellæ*).

For convenience of description the stipule has been here treated as if it were uniformly of the same nature, varying only in form, position, &c. In point of fact, however, the morphological nature of the stipules varies in different plants: sometimes they represent mere excrescences from the petiole; at other times they consist of the lower leaflets of a compound leaf (*Lathyrus*), or they may be leaves formed on a contracted and rudimentary axillary branch.

Lamina.—The lāmina or blade (*b*, fig. 54) of the leaf constitutes the most important part of the structure, and exhibits the greatest variety in its forms, which latter require to be studied in detail, as they often furnish the principal characters for the discrimination of species of Flowering Plants and Ferns. It is ordinarily a flat plate, possessing an *upper* and *lower surface*, turned respectively towards the sky and the earth, two *margins*, a *base*, and an *apex*.

In plants of succulent habit the thickness of the leaves is often so great that the sides are as broad as the surfaces, or they are more or less confounded in a *cylindrical, prismatic*, or some similar form (*Mesembryan-*

themum); and similar external forms are presented by the cylindrical or flattened fistular leaves of the Onion, &c.

If the blade stands alone upon an undivided petiole, or is sessile on the stem, it is called *simple* (figs. 54, 55). Where the petiole is branched, and bears more than one distinct blade, the leaf is *compound* (fig. 64), and its separate blades are called *leaflets.* Both simple leaves and leaflets may be *entire*—that is, the blade may be undivided at its margins; or it may be more or less deeply incised or lobed. The divisions or branchings of such leaves are analogous to the monopodial branching of the stem (p. 38).

Form.—The general form of simple and compound leaves, and the character of the subdivisions of the blade of simple leaves and of leaflets, are associated with the plan of arrangement of the skeleton of the leaf. The solid framework of leaves is composed of woody structures which when large are usually termed *ribs* (*costæ*), the small divisions being called indifferently *nerves* or *veins*. The plan of arrangement of the framework is called the *nervation* or *venation*; the ordinary custom is to call the principal ribs *nerves*, and the smaller branches *veins*. When a distinct principal rib, continuous with the petiole, exists, it is called the *midrib*.

The superabundance of terms is an inconvenience here as in many other departments of Botany. Where it is necessary to select, it is advisable to choose those terms which are least objectionable as not involving hypothetical notions of function.

Nervation or Venation.—The modes of nervation of leaves may be classed under four principal heads:—

1. *Straight-* or *parallel-nerved* (*folia parallelinervia*), when (with or without a midrib) the principal ribs run in more or less parallel lines from the base to the summit (fig. 66).
2. *Curvinerved* (*f. curvinervia*), when the principal ribs run in curves from the base to the summit (fig. 67), or from the midrib to the margin (fig. 68)—differing little from the foregoing, but occurring in broader leaves.
3. *Palminerved* (*f. palminervia*), when the principal ribs radiate from a point at the base of the leaf (fig. 69).
4. *Penninerved* (*f. penninervia*), when the strong midrib gives off the side-ribs at a more or less acute angle, like the blades on the shaft of a feather (figs. 68 & 70).

The term *triple-nerved* (*triplinervia*) is sometimes used for a modification of No. 4, approaching to No. 3, when the midrib gives off on each side near the base a strong side-rib, which runs up within the margin towards the summit. *Feather-ribbed* (*penninerved*) and *hand-ribbed* (*palminerved*) leaves are most common among the Dicotyledons, but they

occur also in many Monocotyledons,—the former, for example, in many Palms, Musaceæ, Zingiberaceæ (fig. 68), &c.; the latter in the Fan-palms,

Fig. 66.

Fig. 67.

Fig. 68.

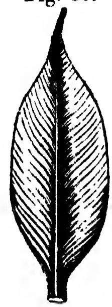
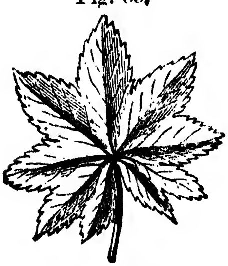


Fig. 66. A parallel-nerved leaf.
Fig. 67. A curvinerved leaf of *Gloriosa superba*, terminating in a tendril.
Fig. 68. A penninerved leaf of *Canna*, with curved secondary nerves.

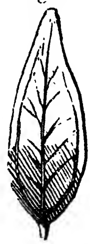
Smilaceæ and Dioscoreaceæ, &c., where there is a transition to a *curved-ribbed* condition (fig. 67), which, with the *straight-ribbed* (fig. 66), is most common in the Monocotyledons. *Straight-ribbed* leaves occur not

Fig. 69.



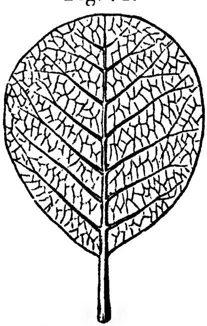
A palminerved serrate leaf.

Fig. 70.



A penninerved entire leaf with a marginal vein.

Fig. 71.



A subrotund, entire, penninerved leaf.

unfrequently in Dicotyledons, as in *Lathyrus*, &c. The most important distinction in the ribbing of the two groups is, that in Dicotyledons the

main rib or ribs branch repeatedly at more or less acute angles, and anastomose by their slender twigs, so as to form a netted or reticular framework; while in most Monocotyledons the branches passing from the main ribs go off nearly at right angles, become suddenly much more slender, and form a kind of square *latticed* or *cancellate* framework when they are strongly developed (fig. 76).

Forms of Leaves.—The general outline of leaves or leaflets is indicated by certain technical terms, such as:—*circular* or *orbicular* (*Hydrocotyle, Tropæolum majus*) (fig. 87); *roundish* or *subrotund*, approaching the fore-

Fig. 72.

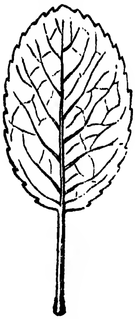


Fig. 73.

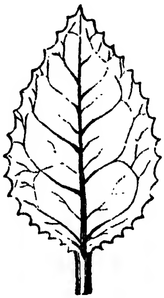


Fig. 74.

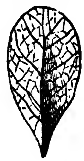


Fig. 75.

Fig. 72. An elliptical serrate leaf.
Fig. 73. An ovate, acute, and dentate leaf; venation arched.

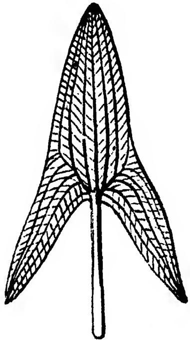
Fig. 74. An obovate entire leaf.
Fig. 75. An entire lanceolate leaf, edges revolute.

going (fig. 71); *elliptical* (fig. 72); *ovate*, egg-shaped with the broad end nearest to the stalk (fig. 73); *obovate*, the same shape, with the narrow

Fig. 77.

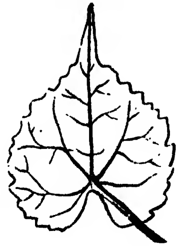
A hastate leaf.

Fig. 76.



A sagittate leaf.

Fig. 78.



A cordate and abruptly acuminate leaf.

end nearest to the stalk (fig. 74); *lanceolate* or lance-shaped (fig. 75); *reniform* or kidney-shaped (fig. 79); *rhomboidal*; *triangular*; or the reverse of this, *cuneate* or wedge-shaped (fig. 88); *deltoid*; *spatulate* or spatula-shaped (fig. 80); *ensiform* or sword-shaped (as in the Garden-flag); *linear*, a long narrow form with parallel margins (fig. 81); *subulate* or awl-shaped, a slender, short linear form soon ending in a point (fig. 82); *acerose*, needle-shaped and rigid (Pines, Juniper, &c.).

Fig. 79.

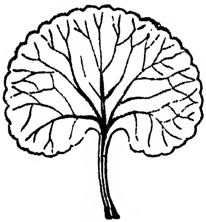
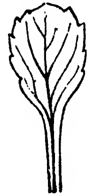


Fig. 80.



Figs. 81, 82.

Fig. 83.

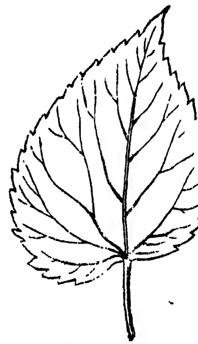
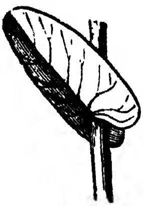


Fig. 79. A reniform crenate leaf.
Fig. 80. A spathulate leaf.
Fig. 81. A linear leaf.
Fig. 82. A subulate leaf.
Fig. 83. An obliquely cordate, serrate, and acuminate leaf.

Sometimes the forms are intermediate between some of the foregoing, in which case two of the terms are combined, such as *ovate-lanceolate*, signifying a leaf broader than *lanceolate*, and with the lower half wider, as in ovate; *linear-lanceolate*, a long and narrow lance-shaped blade, and so on. The term *oblique* is applied to leaves where the portions on either side of the midrib are unequal, as in the Begonias, Lime, Elm, &c. (fig. 83).

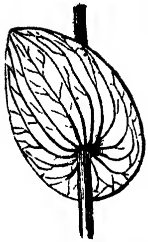
Base of the Leaf.—Special terms are also required to describe the character of the base of the leaf. Thus, *sagittate* or arrow-shaped (fig. 76); *hastate* or dart-shaped (fig. 77); *cordate*, the shape of a heart on playing-cards, with the broad end nearest to the stalk (fig. 78); *obcordate*, the same shape, with the point attached to the stalk (fig. 108); *cordate at the base* may be added to *ovate*, *elliptical*, or other form, where this condition exists; if a *sessile* leaf has a cordate base, it becomes *auriculate* or *eared* (fig. 84) when the borders are free, *amplexicaul* or *clasping* if they adhere to the stem. The last form is a transition to the *decurrent* state. When the posterior lobes of a sessile leaf extend round the stem completely and become confluent on the other side, the stem appears to *run through* the leaf, and the leaves are called *perfoliate* (fig. 85); when the basilar lobes of a pair of opposite leaves cohere on each side, so as to produce a similar condition, the leaves are termed *connate* (fig. 86). Sometimes the blade is gradually narrowed towards the petiole, and becomes *attenuated* at the base; when the blade passes still more gradually into a broad-winged stalk, a *spatulate* form results.

Fig. 84.



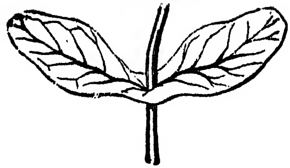
An auriculate leaf.

Fig. 85.



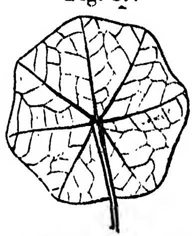
A perfoliate leaf.

Fig. 86.



Connate leaves.

Fig. 87.

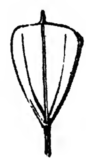


A peltate orbicular leaf.

Another character relating to the base is the mode of attachment of the blade to the petiole. Usually the midrib, or set of primary ribs of the blade, is in a direct line with the petiole; but sometimes the ribs, as they pass from the petiole into the blade, separate and radiate horizontally from the top of the stalk, so that the latter appears to be inserted into the *back* of the leaf; such a condition is called *peltate*, and occurs in *Tropæolum majus* and other plants with *orbicular* leaves (fig. 87).

Apex of the Leaf.—The apex or point of the leaf has certain characters: it may be *acute*, or sharp (fig. 66); *acuminate*, or with the point drawn out gradually (fig. 68), or abruptly (fig. 78); or *mucronate*, when it is tipped with a *spine* (fig. 88). It may also be *obtuse*, when an ordinarily pointed form is suddenly rounded off at the tip; *emarginate*, when there is a shallow notch where the point should be; *retuse*, when a notch of this kind is deep: this last form approaches to the *obcordate* (fig. 108).

Fig. 88.



A cuneate and mucronate leaf.

Margin of the Leaf.—The margins of the leaf are either *entire*, that is, with an unbroken edge (fig. 71); *crenate*, when they exhibit a series of small rounded teeth or scallops (fig. 79); *dentate* when the teeth are acute and pointed radially (fig. 73); *serrate*, when sharp teeth point towards the apex (fig. 83); *retroserrate*, when sharp teeth point towards the base. If there are coarse teeth, the margins of which are again more finely toothed, as in the Elm, the leaves are *doubly serrate* (or *doubly dentate*). Sometimes it is requisite to say, *irregularly toothed*, or *incised*, as in many Thistles; and these teeth, as well as those of regularly dentate or serrate leaves, may be tipped with spines, when they are termed *spinose-serrate*, &c. When the outline exhibits shallow wavy curves, it is sometimes called *repand* (figs. 86 & 87). The margin may also be *rĕvolute*, or rolled back toward the lower face (fig. 75), or *involute* when rolled round on to the upper surface. Sometimes, through excessive growth of the marginal parenchyma, the edges of the leaf are *undulated* (as when the edge of a strip of paper swells from being wetted (fig. 95)).

Lobed Leaves.—A very large number of simple leaves, and of leaflets of compound leaves, are divided more deeply between the principal ribs; to such the general name of *lobed* leaves is often applied, and the more or less distinct parts are called lobes; thus we may have *bilobed* (fig. 89), *trilobed* (fig. 90), and so on, according to the number of the divisions.

Fig. 89.

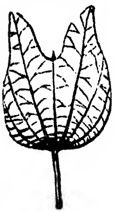


Fig. 90.

Fig. 91.

Fig. 92.

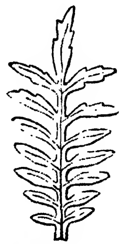


Fig. 93.

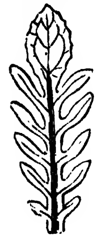
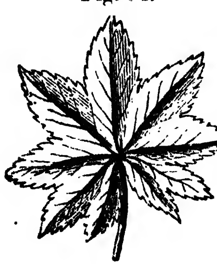


Fig. 89. A bilobed leaf.
Fig. 90. A trilobed leaf.
Fig. 91. A pinnatifid leaf.
Fig. 92. A pinnatipartite leaf.
Fig. 93. A pinnatipartite lyrate leaf.

But it is found requisite in Descriptive Botany to subdivide lobed leaves into more definite classes; of these there are two principal types, defined by the character of the *ribbing*. When the ribs are arranged on the feathered plan, we first take the prefix *pinnati-* (*feathered*), and subjoin to this a word indicating the degree or kind of division, thus: *pinnatifid* (*feather-cleft*), if the broad notches between the lobes extend from the margin to about halfway between this and the midrib (fig. 91); *pinnatipartite*, if the notches extend nearly to the midrib (fig. 92); *pinnatisect*, if the separate lobes are almost free, and merely connected by a narrow strip of parenchyma. Certain less frequent modifications of these forms of the feathered type are conveniently distinguished by technical terms, such as:—*sinuate*, a form either of the *pinnatifid* or *pinnatisect* leaf, when the excavations and the apices of the lobes are rounded, as in the

Fig. 94.



A palmifid leaf, the nine acute lobes serrated.

Fig. 95.

A palmipartite leaf, the five oblong lobes undulated.

common Oak-leaf; *lyrate*, a pinnatifid or pinnatipartite leaf, with the end lobe much larger than the rest (fig. 93); *runcinate*, a *lyrate* or simply *pinnatifid* leaf with the points of the lateral lobes turned towards the base, as in the Dandelion. When the incisions are deep, but very irregular in size and form, the term *laciniate* is sometimes employed.

When the ribs have the palmate arrangement, similar terms are subjoined to the prefix *palmi-* or *palmati-*, or *palmifid* (fig. 94), *palmisect* (fig. 96), and *palmipartite* (fig. 95), according to the depth of the divisions. A special modification of this type occurs not unfrequently, when the lower or outer ribs, and consequently the basilar lobes, turn back more or less towards the petiole; such leaves are generally deeply cut; but the general prefix *pedati-* may be used in the words *pedatifid*, *pedatisect*, or *pedatipartite* (fig. 97), according to the rule given above. Such leaves may be compared to sympodial ramifications; the central lobe is the primary one from which on either side lobes of the second degree are formed; these produce tertiary lobes, and so on, but always on one side only, as in some forms of definite ramification.

Fig. 96.

A palmisect leaf, the segments oblong-obovate serrated.

Fig. 97.

A pedatipartite leaf, the segments lanceolate.

The *bilobed*, *trilobed*, *quinquelobed*, and similar forms are usually referable to the palmate type, and should be more definitely named if they occur in a genus where the leaves exhibit many of these forms, in a *constant* manner; if the leaves are inconstant in the depth of the divisions, these more general names are preferable.

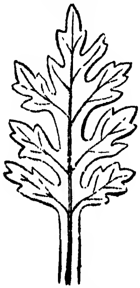
Simple leaves divided on the feathered plan exhibit also more complicated conditions. The primary lobes of a pinnately cut leaf may be subdivided again in the same manner, and the secondary lobes again into tertiary lobes. These are named on the same principles, *bipinnati-*, *tripinnati- -fid*, *-sect*, or *-partite*, according to the degree of division of the *last set of lobes*, *i. e.* of the secondary lobes of bipinnatifid (fig. 98) and the tertiary of tripinnatifid. When the leaves are subdivided a *fourth time*, or even where *tripinnatisect leaves have filiform segments*, the term *dissected* is usually employed.

It must be borne in mind that the terms above defined are applied in a similar manner to the leaflets of compound leaves, next to be described, being subjoined in description to the terms which define the plan and

degree of division of the petiole. They also apply to the bracts, sepals, and all other organs of a leaf-like character.

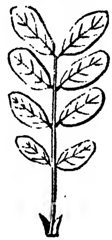
Compound leaves are such as have the petiole branched once or more times before it bears blades; the branches of the petiole are called *partial petioles* or *petiolules*, and are often articulated to the main petiole, which in this case is occasionally termed the *rachis*. Stipels occur at the bases of some partial petioles. The

Fig. 98.



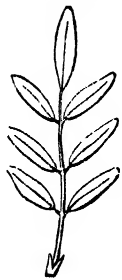
A bipinnatifid leaf.

Fig. 99.



A paripinnate leaf.

Fig. 100.



An imparipinnate leaf.

separate blades of the leaf are called *leaflets* (*foliōla*), or *pinnæ*. Compound leaves may be classed generally into simply, doubly,

Fig. 101.

Fig. 103.

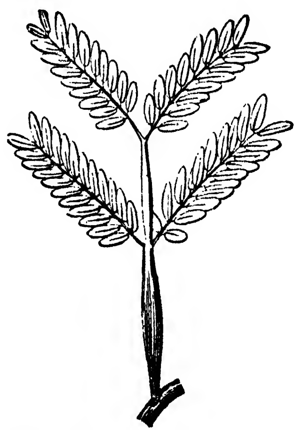


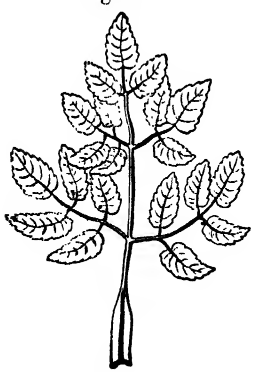
Fig. 102.

Fig. 101. A binate or unijugate pinnate leaf.
Fig. 102. A bipinnate leaf, the pinnæ unijugate.
Fig. 103. A bipinnate leaf, the multijugate pinnæ paripinnate.

triply compound or decompound (*supradecomposita*), according to the number of the successive branchings of the petiole. The ramification follows the same types as that of the ribs of simple leaves, and exhibits analogous subordinate modifications.

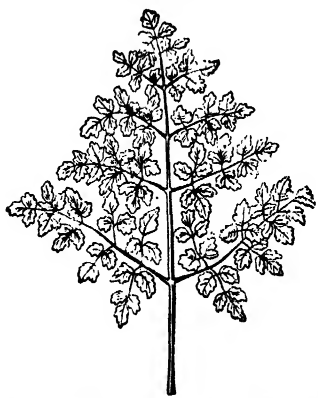
Pinnate leaves are such as have a rachis bearing sessile or stalked lateral leaflets arranged on the feathered plan. Sometimes there is an odd terminal leaflet, when the leaf is *unequally* or *impari-pinnate* (fig. 100). When there is no end leaflet, the leaf is *abruptly* or *pari-pinnate* (fig. 99). *Interruptedly pinnate* means that the opposite pairs of leaflets are alternately large and small, as in *Agrimonia.* The pairs of leaflets are sometimes called *juga*; and if only one pair exists, the leaf is *unijugate* (fig. 101); if more pairs, *multijugate.* If the leaflets are not in pairs, but alternate with each other, the leaf is *alternipinnate.*

Fig. 104.



A bipinnate leaf, the pinnæ imparipinnate.

Fig. 105.



A tripinnate leaf, the pinnæ imparipinnate.

Bipinnate leaves are formed when the main petiole bears secondary petioles with distinct leaflets pinnately arranged (figs. 102–104). *Tripinnate* leaves exhibit an additional (tertiary) series of partial petioles with distinct leaflets (fig. 105). When the division goes beyond the third degree, the leaves are called *decompound* (fig. 106); but it is more common to find bipinnate or tripinnate leaves with their leaflets pinnatifid, -partite, &c.

Palmate (or *digitate*) leaves are such as have a number of distinct leaflets arising from one point, like the ribs of a simple leaf when the plan is palminerved. *Bi-* or *tripalmate* leaves are very rare (Araliaceæ). The only modification appears to be the *pedate* leaf, analogous to the pedatisect simple leaf, but with distinct leaflets (fig. 107).

The terms *ternate, quinate,* and *septēnate* are often applied to palmate leaves with a definite number of leaflets. *Ternate* leaves, however, may occur either on the palmate (fig. 108) or pinnate plan; if on the latter,

there is only one pair of lateral leaflets and a terminal one, but in these the petiole is ordinarily developed between the pair of leaflets and the

Fig. 106.

Fig. 107.

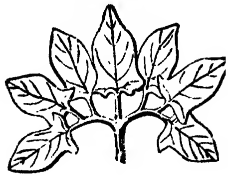


Fig. 108.

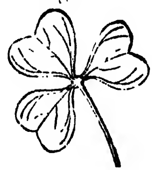


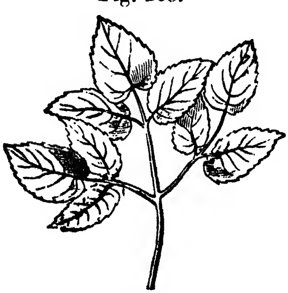
Fig. 106. A pinnately decompound leaf.
Fig. 107. A pedate leaf.

Fig. 108. A ternate leaf with obcordate leaflets.

end one. What are called *biternate* (fig. 109) and *triternate* compound leaves are in most cases *pinnate* leaves with unijugate and terminal leaflets. Such leaves should perhaps be called *ternato-pinnate* or *biternato-pinnate*, &c.

A modified form, apparently intermediate between *pinnate* and *palmate* leaves, like some *ternate* leaves, occurs through the suppression of the main rachis of the bipinnate leaves of some Acacias, giving what may be called a *palmipinnate* form (fig. 110).

Fig. 109.



A biternate leaf.

Fig. 110.

A palmipinnate leaf.

The leaflets of compound leaves of Flowering plants are ordinarily called *pinnæ*, and their subdivisions *lobes*; but in the Ferns, where the leaves are highly compound, and the segments somewhat variable in the degree of confluence, the primary divisions of the leaf are called *pinnæ*, the secondary *pinnules*, and the tertiary *lobes* or *segments*. In highly compound leaves, the ramification of the petiole and subdivision of the laminar structure become less complex toward the apex.

Texture.—The varieties of texture of ordinary leaves depend chiefly upon their anatomical condition; but it is requisite to notice here several terms, such as *membranous*, *leathery* (or *coriaceous*), *succulent*, &c., used in Descriptive Botany, but which scarcely require explanation. In aquatic plants the leaves are usually of slighter texture: when they *float* on water (*natant leaves*) the forms and general external characters are not much modified; but when they grow wholly under water (*submerged leaves*), they are not only more delicate, but are sometimes cut up into fine filiform segments, as in *Ranunculus aquatilis*.

Duration.—The duration is different in different plants. Those which are unfolded in spring and fall off in autumn are called *deciduous*. What are called *evergreen* leaves vary in duration: thus in ordinary evergreens, such as Ivy, Cherry-laurel (*Prunus Laurocerasus*), &c., the leaves remain through the winter and fall off only when the new ones are becoming developed in the spring; while in many Conifers, as in species of *Pinus*, *Araucaria*, &c., the leaves remain attached for many years.

The anatomical structure of leaves exhibits many interesting modifications, related in some degree to the media and climates in which plants grow. These will be more particularly explained in another place.

Surfaces.—The surfaces of leaves, like those of herbaceous stems, exhibit a variety of conditions dependent on the character of the epidermal layer.

Glabrescent is used to signify that a surface, hairy when young, becomes smooth when the leaf is mature, by the hairs falling off. Some smooth surfaces are *shining*; and this is very often the case with the upper surface of evergreen leaves. Hairy surfaces are differently denominated, according to the character of the hairs and their mode of occurrence. Thus a *pilose* surface is covered with scattered soft and small hairs, a *hirsute* with scattered long hairs, a *hispid* with scattered stiff hairs; while a *pubescent* surface is covered closely with short soft hairs, a *villous* closely with longish weak hairs; and when the hairs are curled and interwoven, the terms *silky* (*sericeus*), *woolly* (*lanatus*), *felted* (*tomentosus*), or *floccose*, are applied according to the coarseness of the hairs and the thickness of the coat they form.

What may be called the natural smoothness of surfaces may be interfered with by other irregularities analogous in their nature to hairs. Slight, almost invisible rigid projections render the surface *scabrous*:

hard rigid hair-like processes, called *bristles* or *setæ*, make the surface *setose*; and similar structures still more developed (occurring mostly at the apex and the points of the teeth of leaves), called *spines*, sometimes occur and produce a *spinous* surface. Modified, usually compound hairs, containing oily or resinous secretions, are called *glandular* hairs, rendering a surface *viscous* or *glutinous*, which conditions, however, are sometimes produced by *glands* sunk in the epidermis. The glands are sometimes superficial productions from the epidermis or skin of the leaf, at other times they are outgrowths from the tissue of the leaf itself, as will be described more fully when their structure is considered. *Stings* are long stiffish hairs containing an irritating fluid. *Scaly* (*lepidotus*) surfaces are produced by the occurrence of minute *stalked* flat scales, analogous in their nature to hairs. Sometimes the cuticular layer of the leaf separates in minute scale-like fragments, giving a *scurfy* appearance to the surface, which is termed *furfuraceous* (as in the leaves of the Pine-apple and its allies). The *pruinose* condition is that which results from the conversion of the cuticle into a thin detachable film of waxy matter, of which the "bloom" of plums, grapes, &c. affords an example. These structures will be more fully described under the head of Minute Anatomy.

Characters afforded by Leaves and their Modifications.—In Descriptive Botany attention is specially paid to the *situation*, *attachment*, *duration*, *direction*, *arrangement*, *form* (general and of base, apex, margins, surfaces), *nervation*, *colour*, *texture*, &c., as above described and as further illustrated in the section on the mode of describing plants. With the necessary modifications, the same directions apply to the parts of the flower, &c.

Special Modifications of the Leaf and its Parts.

Under the head of the petiole we have spoken of *phyllodia* as blade-like forms of the petiole (figs. 57 & 58). Not only does the leaf-stalk exhibit this and other modifications, disguising its real nature, but the blade also and the stipules are subject to similar modifications, in which the organ or region is only recognizable by its position and relations.

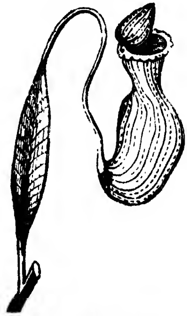
As these metamorphic structures fall under certain types, which are represented in different cases by all the different regions of the leaf, it is most convenient to describe them under special names.

Pitchers (*ascidia*) are structures of the form indicated by their name, produced by peculiar modes of development of the petiole, the blade, or of both together.

One of the best-known examples is found in the *Nepenthes*, or Pitcher-plants, in which a portion of the leaves exhibit a very long stalk, winged at the base, supporting at the extremity a pitcher-like sac of ordinary leafy texture, furnished at its mouth with a little flat plate resembling a lid (fig. 111). The pitcher is commonly explained as a kind of *phyllode*, or

foliaceous petiole, rolled up, and with its margins confluent, the lid-like body being regarded as the *lamina*; but it appears more correct to consider the pitcher as the lamina furnished with a distinct terminal lobe (*operculum*). *Sarracenia*, a North-American bog-plant, has analogous pitchers, which are sessile at the base of the flowering stem; *Heliamphora* (Guiana) has the pitchers less complete, the inner side being slit down as it were for some distance, from the imperfect confluence of the margins of the leaf. In *Dischidia Rafflesiana* the pitchers are plainly formed from the blade, and are open at the end next the petiole; and a similar condition exists in the pitchers formed from the bracts of *Marcgravia* and *Norantea*. Somewhat allied to the above, on a small scale, are the *utriculi*, or sacs of the *Utricularia* (fig. 112), little bladder-like organs, closed at first by a lid, developed from some of the lobes of the leaves of these aquatic plants, and apparently serving as "floats" and as traps for insects. In other aquatics (*Trapa*, &c.) floats are formed by *inflated petioles*, constituting as it were indehiscent pitchers, surmounted by ordinary blades.

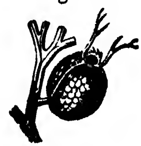
Fig. 111.



Pitcher of *Nepenthes*.

Teratological illustrations of the origin of pitchers are occasionally afforded by garden plants. This has been especially observed in the Tulip, in which the leaf next the flower-stalk has been found with its margins completely confluent into a kind of spathe, which bursts by a transverse fissure to allow the flower to appear.

Fig. 112.



Utriculus or air-sac of *Utricularia*.

Tendrils (*cirri*) are thread-like processes, curled spirally, by

Fig. 113.

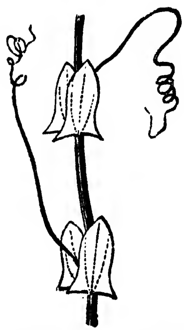


Fig. 114.

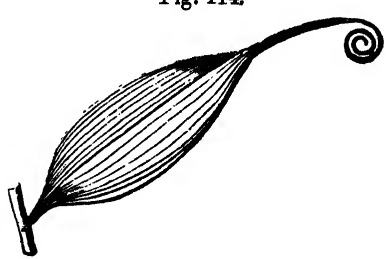


Fig. 113. Leaves of *Lathyrus Aphaca*, represented by tendrils, with large foliaceous stipules.
Fig. 114. Leaf of *Gloriosa superba*, prolonged into a tendril.

which weak-stemmed plants attach themselves to foreign bodies. They may be modifications of any part of the leaf or of a branch.

In *Lathyrus* the blade-structure of the leaf is more or less deficient in different species. In *L. Aphaca* (fig. 113) it is wholly wanting, the petiole running out into a tendril, which may be regarded as consisting either of the leaf-stalk alone, or of this and the midrib of the lamina. In *L. odoratus* (Sweet Pea) the pinnately compound leaf has one pair of leaflets, and usually one pair of tendrils, and a terminal tendril in the ordinary place of the remaining leaflet. In the edible garden Pea there are several pairs of leaflets, and often several pairs of tendrils, with a terminal one. In *Gloriosa superba*, a Liliaceous plant, the broad simple lamina runs out into a terminal tendril (fig. 114). In *Smilax* (fig. 115) the two stipules are represented by a pair of tendrils; while in the Cucurbitaceæ one tendril only occurs, which some regard as a stipule, others as a metamorphosed leaf, others, again, as a branch or peduncle.

Fig. 115.

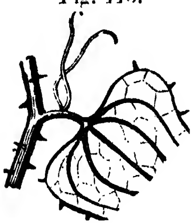


Fig. 116.

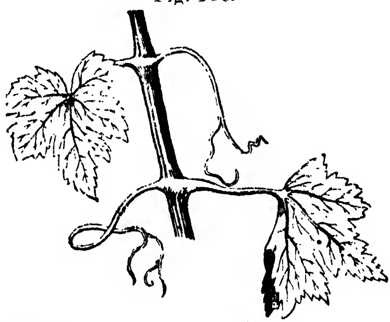


Fig. 115. Tendrils of *Smilax aspera*, formed from the stipule
Fig. 116. Leaves and tendrils of the Vine.

The tendrils of the Vine (fig. 116) are modified flowering branches, originally terminal but displaced during growth so as to become placed opposite to leaves, and often tuberculated by the existence of abortive flower-buds. The nature of the axillary tendrils of Passion-flowers is similar.

Spines (*spinæ*) or thorns are hard, sharp-pointed woody processes, formed, like tendrils, by modification of entire organs or parts of such.

Thus in the common Berberry some of the leaves are represented by compound spines, in the axils of which arise fasciculate groups of leaves. In the False Acacia-tree (*Robinia Pseudacacia*) the stipules are represented by a pair of spines at the base of the petiole (fig. 117), while in certain species of *Astragalus* the petioles are converted into spines after the fall of their leaflets.

Fig. 117.

Base of the leaf of *Robinia*, with stipules developed as spines.

Spinous processes are developed upon the petiole in the upper part of the leaves of certain Palms (*Plectocomia*), and even on the surfaces of some leaves, as in some varieties of Holly.

True spines, however, are more frequently dependencies of the stem: thus in the Gooseberry they are developed from the *pulvinus*, below the base of the petiole. In the Black-thorn (*Prunus spinosa*) the spines are real branches (fig. 118), as also are the spines of *Gleditschia triacanthos* (fig. 119), and the principal spines of Furze (*Ulex*), in which, however, the points of the leaves are spinous also.

Fig. 118.

Fig. 119.

Fig. 118. Spinous branch of *Prunus spinosa* (Black-thorn).
Fig. 119. Spinous branch of *Gleditschia triacanthos*.

Prickles (*aculei*), properly so called, are sharp woody processes, straight or curved, occurring upon stems, leaf-stalks, at the points or on the margins, or upper surface of leaves. They are distinguished from true spines by their originating from the epidermis, like hairs, glands, &c., and by having no connexion with the internal woody substance of the stem or ribs of the leaves &c.

Glands.—This is perhaps the most convenient place to mention the nodular or discoid glandular bodies that occur in connexion with certain leaves, as on the petioles of *Passiflora* &c. They are distinct in their nature from the epidermal glands before mentioned, and considerable attention has been directed to them on morphological grounds; hence they will be adverted to again in speaking of the flower.

Sect. 5. The Leaf-bud.

The bud is a compound structure, composed of a solid conical basis, or growing point, supporting a number of rudimentary leaves. In the *leaf-bud*, or rudiment of a shoot, the conical base represents the future stem, with its internodes as yet undeveloped; the scales are either entirely rudimentary leaves, or a portion of

them on the outside are modified leaf-structures, forming scales for the protection of the inner leaves, and destined to fall off when the bud expands. In the early conditions, the *flower-bud* is essentially analogous to a leaf-bud; but its ultimate history is different, as will be shown hereafter.

Many of the general characters of buds have been described already, under the head of the stem (pp. 34, 35); but there are some other more special peculiarities which require separate treatment here; and repetition of certain more important facts will not be disadvantageous.

In all seeds, except those of the few Orders which present an incomplete or acotyledonous embryo, the young plant is possessed, at or soon after the time of germination, of a rudimentary bud, called the *plumule*, situated at the point of growth of its ascending axis (figs. 120–122). This is the *terminal bud* of the young

Fig. 120.

Fig. 121.

Fig. 122.

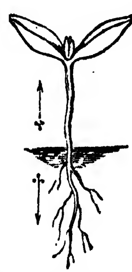


Fig. 120. Monocotyledonous embryo of *Potamogeton*, cut through perpendicularly: *a*, radicle; *b*, cotyledon; *c*, plumule.

Fig. 121. Dicotyledonous embryo of the Bean (*Faba*), with the cotyledons, *b' b'*, separated: *a*, radicle; *c*, plumule.

Fig. 122. Diagram of a germinating Dicotyledon, with the plumule or terminal bud between the expanded cotyledons.

plant; and stems and shoots only retain the power of elongating so long as they possess such a bud at their extremity. When it is removed by artificial means, by frost, or, by metamorphosis, is replaced by a flower, the onward growth of the shoot ceases.

Axillary buds are the origin of the ramifications of stems. They are developed in the *axils* of leaves; and as they unfold into secondary axes, they become the terminal buds of such shoots. Other axillary buds are formed at the nodes of these secondary shoots, to repeat the ramification by developing into tertiary axes according to the type of the species (see p. 34).

Adventitious or **accidental buds** are those which appear, contrary to the usual order, at indefinite points, unconnected with the axils of leaves. Generally speaking they are abnormal products,

presenting themselves under special conditions. They usually occur on organs in a very active state of vitality, subjected to stimulating external conditions, especially where, through natural or artificial operations, there is an absence or insufficiency of normal buds to carry off the developmental energy of the plant or organ.

Adventitious buds may be produced from any part of the plant. With regard to those produced on old stems, as in pollarded trees, or those which occur on subterraneous stolons, as in the Rose, Ash, &c., it is not always easy to decide without dissection whether the buds are really adventitious or merely latent axillary buds stimulated into development; but true adventitious buds do occur. The production of adventitious buds on true roots has been frequently observed, as in *Pyrus japonica*, *Maclura aurantiaca*, *Paulownia imperialis*, &c.; and the *Anemone japonica* is commonly propagated by cuttings of the root. The formation of adventitious buds on leaves is a still more remarkable physiological phenomenon. It has been observed chiefly in succulent leaves, but it is not exclusively confined to them. When it takes place, the first sign of development is the production of adventitious roots, followed by the formation of a cellular nodule which subsequently assumes the character of a bud. Among natural examples, the leaves of *Cardamine pratensis* have been observed to form adventitious roots on the lower side when lying upon wet ground, and even to produce buds; the leaves of several Ferns, such as *Woodwardia radicans*, root at the end, and produce buds which propagate the plant; and many similar instances might be cited. Artificial production of buds on leaves is now a familiar fact, under the influence of heat and moisture, not only on the scales of bulbs, but on the green leaves or even fragments of the leaves of *Bryophyllum*, *Echeveria*, *Gloxinia*, *Gesnera*, *Hoya*, &c.; the *Orange* and the *Aucuba japonica* may also be propagated by their leaves. Sometimes the leaves produce rootlets alone, and remain stationary without having force enough to develop a bud.

The formation of adventitious buds on leaves, especially in *Bryophyllum*, where a number are often produced, arranged on the margin, is of great interest in connexion with the theories of the structure of ovaries and the origin of the ovules.

Bud-scales.—The bud which continues the growth from the plumule of a germinating plant (fig. 122), and the axillary buds produced during a season of active growth, are composed of rudimentary leaves; but the winter- or resting buds formed on most deciduous trees and shrubs of temperate climates present the modified foliar organs called *bud-scales* (*perulæ*), analogous to the scales of bulbs and other subterraneous buds of herbaceous plants (figs. 123 and 124). Buds without scales are called *naked*. The *scales*, when present, are mostly of leathery or membranous texture, and are often clothed more or less densely with hairs, which are sometimes glandular and produce a resinous or glutinous secretion, which exudes when the buds swell.

When winter-buds swell and open, throwing off their scales, the internodes between the latter do not elongate, while those between the nascent leaves do; consequently the starting-point of each annual period of growth of a branch with an indefinitely developed terminal bud is indicated by a little band of scars marking the place where the scales stood.

Fig. 123.

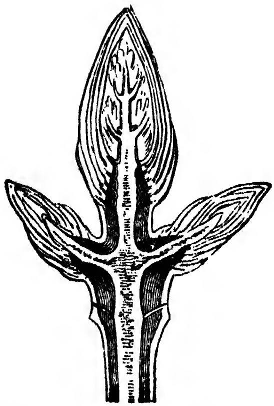
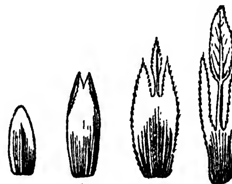


Fig. 124.



a *b* *c* *d*

Fig. 123. Section of the end of a shoot of the Horse-chestnut, showing the terminal and two axillary buds; the terminal bud contains an inflorescence, surrounded by scales and rudimentary leaves.

Fig. 124. Bud-scales *a*, *b*, and rudimentary leaves *c*, *d*, from the winter-bud of *Prunus Avium*.

The first two scales of a bud of a dicotyledonous plant, like the two cotyledons of the embryo, usually stand right and left of the axil on which the bud arises; the succeeding scales assume at once the regular character of arrangement of the leaves of the species.

In winter-buds there is commonly a gradual transition from the pure scale to the true leaf (fig. 124), as occurs in bulbs; and the scales, as in bulbs, are referable chiefly to the vaginal or petiolar portion of the leaf. But the scales originate differently in different cases: thus we have *petiolar scales*, as in the Walnut and Horse-chestnut; *stipular scales*, as in the Vine, Oaks, Elm, Poplars, &c.; in this case, however, especially in the outer scales, the stipules and the petiole are confluent into one organ (*Prunus*, *Rosa*, &c.) (fig. 124). *Foliaceous scales* are formed by the blade of the leaf, of which we have examples in the Lilac, Maples, Coniferæ, &c.

Vernation.—The mode in which rudimentary leaves are arranged in leaf-buds is called the vernation, and furnishes important systematic characters. Two points have to be regarded here, viz.:—1, the arrangement of the leaves in relation to each other; and,

2, the manner in which each separate leaf is folded. The general arrangement is called *imbricate* or *valvate*, according as the margins of the leaves overlap one another or simply meet without overlapping; but more minute distinctions are observed, and these depend to a great extent on the phyllotaxis of the species. Thus with the $\frac{1}{3}$, $\frac{2}{5}$, or other spiral plan, we have usually triquetrous (fig. 126) or quincuncial (fig. 128) *imbricate* buds proper; with alternate $\frac{1}{2}$ or distichous leaves the vernation may be *equitant* (fig. 125), where each leaf, sharply folded (*conduplicate*), completely

Fig. 125.

Fig. 126

Fig. 127.

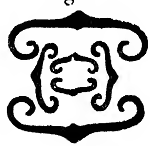
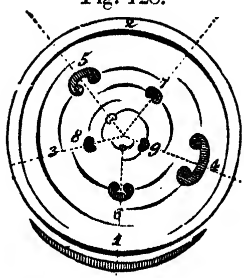


Fig. 128.



Sections through Buds, showing their reciprocal vernation.
Fig. 125. Imbricated, and equitant (of a Grass).
Fig. 126. Imbricated, triquetrous (of a Carex).
Fig. 127. Induplicate, decussate (of the Apple).
Fig. 128. Imbricated, quincuncial (of a Poplar).

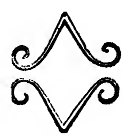
embraces its successor (as in the Flag), or *half-equitant* or *obvolute*, where the leaves are similarly folded, but each leaf embraces only one (lateral) half of the blade of its successor. *Valvate* buds occur mostly where the leaves are opposite; a modification of this form exists where the margins of the leaves are rolled inwards (fig. 127), and is called *induplicate vernation.*

The individual leaves in a bud are either *flat*, *folded*, or *rolled*. For the first, of course, no special term is requisite. Of the folded leaves we have:—*reclinate*, or inflexed, where the leaf is folded horizontally, so that the point is brought down to the base (*Liriodendron*); *conduplicate* (fig. 125), where the leaf is folded perpendicularly at the

Fig. 129.

Fig. 130.

Fig. 131.



Sections through leaves showing their individual vernation.
Fig. 129. Vernation of a plicate leaf.
Fig. 130. Vernation of a convolute leaf.
Fig. 131. Vernation of revolute leaves.

midrib and the lateral halves are placed face to face (Oak); and *plicate* (fig. 129), where the blade exhibits several perpendicular folds, as in a fan (Vine, Beech, Maple, Currant, &c.); this last is often combined with the preceding. When rolled up, also, the rolling may take place in either direction: where the apex of the leaf is rolled down toward the base, as in the Ferns and in the flower-stalk of *Drosera*, it is *circinate*; if the leaf is rolled up from side to side like a plan, with only one edge free, as in the Cherry &c., it is *convolute* (fig. 130); when both margins are rolled inward toward the midrib, it is *involute* (fig. 127); and when both margins are rolled outward toward the midrib, it is *revolute* (fig. 131).

Sect. 6. The Inflorescence.

In all Flowering Plants, a portion of the buds change their character at certain periods and in certain situations. They cease to elongate and produce true leaves, while the foliaceous organs of which they are composed are gradually developed into that assemblage of organs which constitutes a flower.

So intimately are the leaf-bud and flower-bud related, that, under peculiar conditions, producing monstrous growths, flower-buds are seen to expand into tufts of green leaves, or imperfect flowers to throw out leafy shoots from their centres; such cases are often observed, for instance, in cultivated Roses; and leaf-shoots may likewise exhibit more or less of the characteristics of a flower, &c.

Flower-buds are subject to the same laws of arrangement as leaf-buds. The buds which commence the growth of the reproductive structures may be at once developed into solitary flowers, or, as is more common, the blossom-buds unfold into a system of branches terminating in flowers, the branches all originating in the axils of modified leaves, called *bracts*. The solitary flower, or the connected system of flowers arising from one point, is called the *inflorescence*, which is either *terminal* or *axillary*.

The inflorescence is produced from the terminal bud, or from this and one or more of the upper axillary buds, in most annual plants; and there is often a gradual transition from the true-leaf stem into the bract-region, or inflorescence. The same is the case, to a great extent, with the flowering stems of biennials. The inflorescence of herbaceous perennials, bulbs, &c. is either terminal or axillary, as is that of arborescent plants. In the Horse-chestnut (fig. 123) and Lilac, for example, the terminal bud usually ends in a blossom, while in the Apple and its allies the inflorescence is axillary.

When the inflorescence is developed from the terminal bud of an unbranched stem, the growth of the plant ends in the blossoming, as is the

case in the *Agave*, the Talipot and other Palms, which require a number of years to bring them to the point of flowering, after which they die away, like a bulb with a terminal inflorescence, the plant being sometimes propagated at the same time by offsets from the axils of the lower leaves. The inflorescence of other unbranched Palms, such as the Cocoa-nut, is axillary, and thus may be repeated indefinitely.

A flower-bud may be either *sessile* or *stalked*; if the latter, the stalk is called the *peduncle*. The branches of the peduncle or the slender stalks bearing the individual flowers are called *pedicels*, and that portion of the main flower-stalk or axis from which the pedicels spring is sometimes called the *rachis*.

Solitary flowers.—The simplest forms of inflorescence consist of solitary flowers, either terminal (as in the Tulip), or axillary, when simple peduncles arise from the axils of ordinary leaves (as in *Lysimachia Nummularia*, see also fig. 13, p. 23).

The term *scape* (*scapus*) is applied to a stem devoid of true leaves, arising underground from the terminal bud or from the axil of a scale or leaf of a rhizome, bulb, &c. It may bear a single flower, as in the Tulip, or a group of flowers, as in the Hyacinth, or a "head" of flowers, as in the Daisy, Dandelion, &c.

When solitary flowers arise in the axils of ordinary leaves, the flower-leaf or bract-region of the stem is scarcely represented (fig. 13), or, at least, does not differ from the true-leaf region; but, generally speaking, those parts of the stem which bear flowers are separated to a certain extent from the true-leaf region, and form a distinct association of parts, representing the bract-region. In the flowering stems of annuals and biennials it is often difficult to draw a line at the boundary of the true-leaf region and the inflorescence, from the leaves passing insensibly into bracts from below upwards, as in the Foxglove.

Bracts.—The leaves of the flower-leaf region of the stem are called bracts. They are mostly smaller than the leaves preceding them, usually simple, and often scale-like, or *glumaceous*, consisting of the vaginal portion of the leaf only. In the generality of cases they are green; but not unfrequently they are tinged with the same colours as flowers (as in various Sages), or are even entirely petaloid. In other cases they are membranous, and then often very transient in their existence. The diminutive term *bracteole* is applied to the small bracts which occur on the pedicels of certain plants, often in pairs.

The term *bracteole* is loosely applied by some authors to the smaller bracts of a compound inflorescence; but it is much more convenient to use the term *bract* for all leaves which subtend branches of the inflorescence, and to call those scales *bracteoles* which occur on an ultimate pedicel, as in many Leguminosæ. In Monocotyledons there is usually

a single bracteole, while in many Dicotyledons there are two; in the former case the anterior surface of the bracteole is directed towards the primary axis from which the flower is produced, in the latter the two bracteoles are lateral or oblique to the axis.

As a general rule, all ramifications of inflorescence arise in the axils of bracts; but the bracts are sometimes regularly abortive, as in the Cruciferæ. On the other hand, we sometimes find the lower part of the inflorescence crowded with bracts with empty axils.

Spathe.—In many plants the bract subtending the whole inflorescence or its principal branches is large, and forms a kind of sheath, called a *spathe*. Sometimes this surrounds only one flower, as in some Daffodils, &c., where it is of membranous texture; the membranous spathe of the Onion and its allies encloses a dense inflorescence; in the Araceæ (fig. 133) it is still more developed, and sometimes of petaloid structure, as in the so-called Trumpet-lily (*Richardia æthiopica*), where it encloses the club-like inflorescence; while in the Palms (fig. 134) it assumes enormous dimensions and a leaf-like or even fibrous texture, forming a sheath to a large and greatly ramified inflorescence.

Involucre.—In other cases, several bracts are collected together, forming a whorl or densely packed spire, called an involucre. The Umbelliferæ have frequently verticillate involucres at the base of the umbels, and sometimes secondary whorls or *involucels* at the base of the secondary umbels (fig. 140). In the Compositæ also, where the flowers are crowded on a common receptacle, the bracts form an involucre (figs. 141–146); smaller scale-like bracts occurring among the florets of these capitula are called *paleæ* (figs. 145 & 146). Other examples of involucre are furnished by the *cupules* of the Oak, Beech, Filbert, &c., wherein the bracts are united or not disconnected at the base; also by the outer *glumes* or scales of the spikelets of Grasses.

Forms of Inflorescence.—The different forms of the Inflorescence are divisible into two classes:—1, the *indefinite*, where the terminal bud of the main or primary axis does not form a flower, the flowers being borne on *secondary lateral* branches, which are as a rule smaller and weaker than the main axis; and, 2, the *definite*, where the *primary* axes either bear *terminal* flower-buds, while the succeeding flowers spring from *secondary axillary* branches produced lower down, and subsequently to the terminal bud, or branch in a forked manner without producing a flower in the centre of the fork. The secondary branches are here as strong or stronger than the main axis. The forking is not neces-

sarily a true dichotomy, but may apparently be so owing to the abortion of the terminal bud.

Examples of the indefinite form are seen in the Cruciferæ, especially the Wallflower, where a few flowers at first appear in a tuft, while the seed-vessels are afterwards wide apart on an elongated raceme, the uppermost being the youngest. In the Foxglove and similar plants we may produce a very long development of the indefinite structure by picking off the lower flowers as they wither, when, as no seed is formed, the indefinite terminal bud retains its energy, and continues to lengthen until the plant is exhausted. On the other hand we observe, in the Sweet-William, the Elder, and the Hydrangea, the centre flower of a tuft opens first, and the *definite* inflorescence becomes wider and wider, but never elongates or grows out in the centre.

Fig. 132.

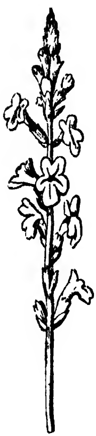


Fig. 133.

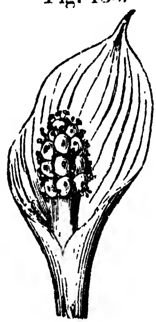


Fig. 134.

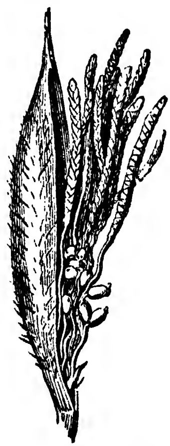


Fig. 135.

Fig. 132. Spike of *Verbena officinalis*.
Fig. 133. Spadix and spathe of *Calla*.
Fig. 134. Compound spadix and spathe of a Palm.
Fig. 135. Compound spike, with spikelets, of *Lolium*.

When an *indefinite* inflorescence is elongated the lowermost flowers open first, while if it be of a flat-topped or crowded character, the outermost flowers open first and the central ones last, as in the capitula of the Compositæ. Hence the indefinite forms of inflorescence are sometimes called *centripĕtal* or *progressive*, and the definite *centrifŭgal* or *regressive*.

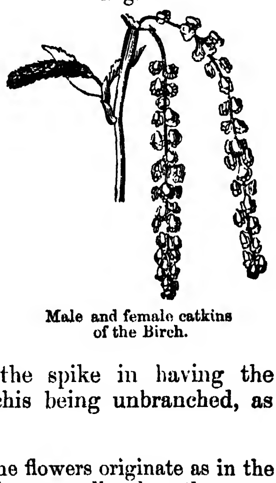
There is an exception to the ordinary regularity in the capitula of *Dipsacus* (Teazel), where the florets open first halfway up, and then proceed both centripetally and centrifugally.

Forms of Indefinite Inflorescence.—Of the Indefinite Inflorescence the following are the most important forms :—the *spike*, the *raceme*, the *corymb*, the *umbel*, and the *capitulum*.

Spike.—The spike is a long simple axis or *rachis* bearing sessile flowers, either standing at intervals, as in the Vervain (fig. 132), or crowded, as in the common Plantain and many Sedges.

Several modifications of the spike have distinct names. When the rachis bears large, persistent, imbricated bract-scales, it forms a *cone* or *strobile*, as in the Firs and Pines. When it is thick and fleshy, with the flowers more or less imbedded in it, the term *spadix* is applied, of which the Araceæ furnish examples (fig. 133) ; the same term is conveniently retained when this fleshy axis is branched, as in the Palms (fig. 134). The so-called spikes of many Grasses, such as Wheat, Barley, Rye-grass (fig. 135), Cat's-tail-grass, &c., are also compound spikes, since in place of single flowers the rachis bears *spikelets* or short axes with several sessile flowers. The term *catkin* (*amentum*) is applied to the pendent, often caducous, spike-like inflorescence of the Willow, Poplar, Birch (fig. 136), and the male inflorescence of the Oak, Filbert, Chestnut, &c.; in these the bracts have sometimes *one*, sometimes *several* flowers in their axils. The flowers in catkins are usually unisexual.

Fig. 136.



Male and female catkins of the Birch.

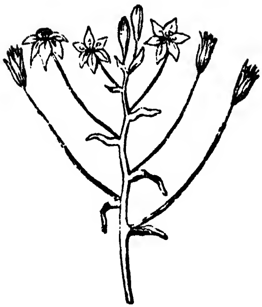
Raceme.—The raceme differs from the spike in having the flowers distinctly stalked, the main rachis being unbranched, as in the Hyacinth, &c.

Corymb.—The corymb is formed when the flowers originate as in the raceme, but the lower ones are raised on longer stalks than the upper ones, so as to bring them all nearly on a level, as in *Ornithogalum* (fig. 137), &c.

As already noticed, a corymbose inflorescence sometimes grows out into a raceme while the fruits are ripening, as is seen in many Cruciferæ. The relation between the two forms, or, more properly, between the panicled and the corymbose state of the same inflorescence, is well seen in comparing a Cauliflower as fit for the table with the expanded inflorescence of the same plant when allowed to run to seed.

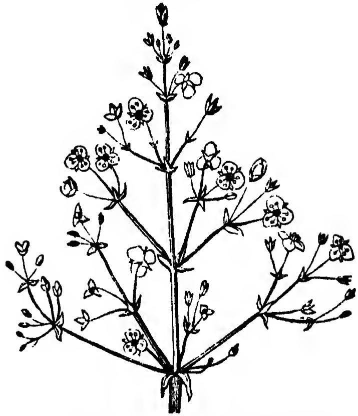
Panicle.—A panicle is formed when the main rachis is more or less branched ; it is hence a series of racemes on a branched rachis. The term *panicled* is often used in a general sense, to signify a much-branched inflorescence, whether definite or indefinite.

Fig. 137.



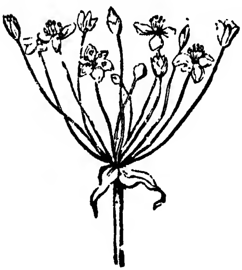
Corymb of *Ornithogalum.*

Fig. 138.



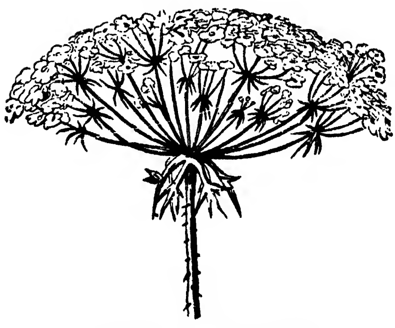
Panicled cyme of *Alisma Plantago.*

Fig. 139.



Umbellate inflorescence of *Butomus umbellatus.*

Fig. 140.



Compound umbel of the Carrot.

Umbel.—The *umbel* is formed by a number of single flowers borne on long stalks of nearly equal length arising from one point, as in the common Cherry, the Cowslip, &c. In the family of Umbelliferæ, so called from the prevalence of this inflorescence, the umbels are mostly *compound* (fig. 140); that is, the first set of peduncles do not bear flowers, but secondary sets of radiating branches, forming *umbellules*, or secondary umbels. Inflorescences of this general character are termed *umbellate* even when definite.

Umbels usually have an involucre at the base of the radii, as noted above. The simple umbels of the Onion group are originally enclosed in a membranous spathe.

Capitulum or Head.—The capitulum is mostly formed by the rachis expanding into a thickened mass, surrounded by an involucre of overlapping bracts, presenting a convex, flat, or concave surface (*common receptacle*), upon which are crowded a great number of sessile flowers, as in the families of Compositæ and Dipsaceæ (figs. 141–146). In the Compositæ there are often little mem-

Fig. 141.

Fig. 142.

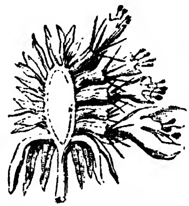


Fig. 143.

Fig. 144.

Fig. 141. Capitulum of *Scabiosa*.
Fig. 142. Vertical section of the capitulum of *Scabiosa*.
Fig. 143. Receptacle of the Daisy with the florets removed.
Fig. 144. Receptacle of Dandelion with the florets removed; bracts of the involucre reflexed.

Fig. 145.

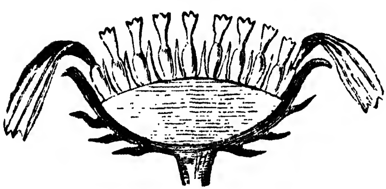


Fig. 146.

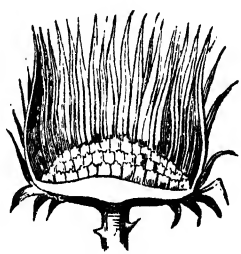


Fig. 145. Section of a capitulum of a Composite plant with paleæ at the base of the central tubular and of the marginal ligulate florets.
Fig. 146. Section of an empty capitulum of a Composite plant with a paleaceous receptacle.

branous bracts (*paleæ*) at the outside of each flower (figs. 145, 146); in the Dipsaceæ each flower is surrounded by a cup-like involucel (fig. 142).

The flowers crowded together in the capitula of Compositæ are small and of various forms, so arranged as to give the whole the outward aspect of a single flower; hence this inflorescence was formerly called a *compound flower*, and its involucre a *common calyx*.

The flowers in the capitula of the Compositæ are called *florets*; and different names are applied to this inflorescence, according to the mode of arrangement of the florets. In the Daisy, we observe a yellow middle *disk* and a white or pinkish *ray*; the *disk* is composed of florets different in character from the spreading florets of the *ray* (fig. 145). Some capitula are wholly *discoid*, such as those of Groundsel (*Senecio vulgaris*), of Thistle, &c.; others are wholly *radiant*, such as those of the Dandelion, Lettuce, &c.

It should be observed that cultivation tends to convert tubular florets into spreading ones, and so to obliterate the yellow disk or "eye," as we observe in the Dahlia, garden Daisy, &c.

Capitula of less marked character are found in other families, where, however, the involucre is wanting; for example, the flowers of Clover (*Trifolium*) have a capitular arrangement, as also those of many Proteaceous plants (*Banksia*). In the Fig the peduncle or common receptacle is fleshy and excavated (fig. 147), the flowers being inside and developed centrifugally; in *Dorstenia* (fig. 148) the receptacle is flat or slightly concave on the top, while in *Artocarpus* and other cases the flowers are on the outside of a convex peduncle. These forms of inflorescence are only slight modifications of the *capitulum*. Such inflorescences must not be confounded with the concave top of the flower-stalk enclosing the carpels of a single flower, as in the Rose.

Fig. 147.

Fig. 148.

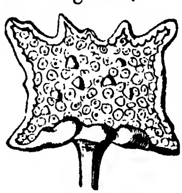


Fig. 149.

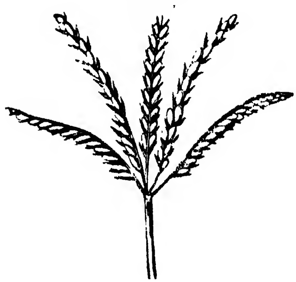
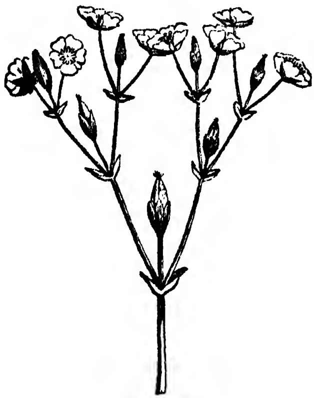


Fig. 147. Inflorescence of the Fig; the flowers inside the excavated fleshy receptacle.
Fig. 148. Inflorescence of *Dorstenia*; the flowers imbedded in the fleshy receptacle.
Fig. 149. Compound umbellate spike inflorescence of *Digitaria*.

Forms of Definite Inflorescence.—The forms of definite inflorescence are also termed *cymose*, the term *cyme* (fig. 150) being very general in its application; for it is used in reference to a

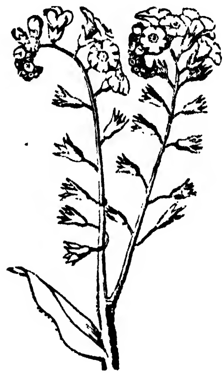
number of forms more or less resembling outwardly the raceme, corymb, and others of the indefinite type, but all agreeing in

Fig. 150.



Dichasium or dichasial cyme of *Cerastium.*

Fig. 151.



Scorpioid cyme of *Myosotis palustris*

producing a primary terminal flower on each shoot, and continuing the subsequent evolution by secondary axillary development, the development of the lateral shoots being thus more vigorous than that of the primary shoot.

The loose cymose inflorescence of many Caryophyllaceæ illustrates the *definite* mode of growth very clearly ; the primary axis terminates in a flower (figs. 150, 152), then branches arise in the axils of a pair of bracts lower down ; these branches repeat the process, and their branches again, until the flowering shoot is exhausted.

Cymose inflorescences admit of division into two principal groups, according as they are *monopodial* or *sympodial* (see *ante*, p. 39).

Monopodial Cymes.—Each branch of the inflorescence is here terminated by a primary flower (fig. 152, I), below which are developed two or more secondary flower-stalks, one on each side, and each in its turn surmounted by a flower (fig. 152, II, III, IV). The simplest form of this is the *dichasium* (figs. 150, 152), the *cyme bipare* of the French. There is no true *dichotomy* in such instances, the appearance of such being due to the superior development of the side branches as compared with that of the terminal one.

Sympodial Cymes.—These may be called unilateral, as in them the secondary branches of the same degree are developed on one side

only: thus the primary flower-stalk or axis ends in a flower: beneath this arise not two branches, one on either side, as in a dichasium, but one only, this one being terminated by a flower like the primary branch and giving off a tertiary branch as before (fig. 153). The flower-stalks here appear to be opposite to the

Fig. 152.

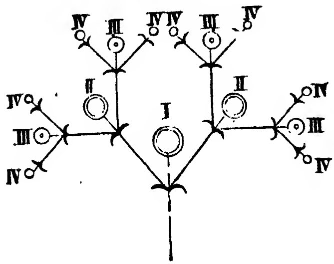


Fig. 153.

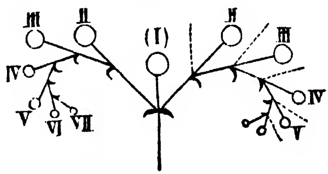
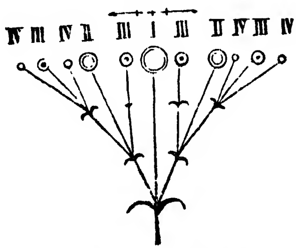


Fig. 154.



Figs. 152–154. Diagrams illustrating the centrifugal development of cymose inflorescences. Fig. 152 a globose dichasial cyme; fig. 153 a sympodial scorpioid cyme, the dotted lines indicate the suppressed branches; fig. 154 a corymbose cyme. One of the lateral branches at III is abortive.

bracts; but the bract in this case belongs not to the flower-stalk immediately opposite to it, which is a primary formation, but to the secondary flower-stalk which springs from its axil.

The subsidiary flower-stalks are sometimes developed all on the same side when the inflorescence becomes curled from the greater growth on one side than on the other. Such cymes are called *scorpioid cymes* (fig. 151). At other times the subsidiary pedicels or flower-stalks are developed alternately, first on one side and then on the other, when the inflorescence has a zigzag shape. When the main rachis is a sympode (p. 39), and the flowers, instead of being all on one or on two opposite sides, are disposed spirally, the term *helicoid cyme* is given. In these forms of cyme one of a pair of peduncles is generally systematically suppressed, and this happens successively on one side of the main rachis of the inflorescence, or,

as has been said, alternately, now on this side, now on that. This main rachis is therefore not formed by one continuously growing shoot, but by a succession of shoots of different generations placed one over the other in definite order, thus forming a *sympode* (see *ante*, p. 39). In this manner we may have *spicate* or *racemose sympodial cymes* closely resembling, on a superficial inspection, spikes or racemes. If the bracts are present the true nature of the inflorescence is apparent, because in that case the peduncles are on the *opposite side of the axis to the bracts*, as in *Helianthemum*. It often happens, however, in these cases that the bracts are wholly wanting, as in Boraginaceæ, in which the scorpioid cyme has been attributed to repeated forking of the growing point; but the sympodial theory is the more probable.

Forms of Cymes.—The form of the cyme is sometimes further indicated by such terms as a *globose cyme*, a *linear cyme*, and so on. When the flowers are nearly sessile, forming a dense flat-topped bunch, such as we see in the Sweet-William and other species of *Dianthus*, the term *fasciculus* is sometimes used. Where a cymose tuft of only a few flowers, crowded together in this way, occurs in the axil of an ordinary leaf, the inflorescence is sometimes called a *glomerulus*, as in many of the Labiatæ.

Compound Inflorescence.—Some plants, especially herbaceous perennials, have *compound inflorescence*, wherein the flowering region of the stem appears to be composed of a number of distinct inflorescences arranged on a regular plan. The plan of the ramification of the main axis may be the same as that of the individual inflorescence, as in the Umbelliferæ, where both the primary and the secondary umbels unfold centripetally; sometimes the separate inflorescences are arranged in a different form belonging to the same class, as in the case of the umbellate collection of spikes in certain Grasses (*Digitaria*, fig. 149), &c.

Mixed Inflorescence.—In other cases there is a mixed condition, since in many Compositæ the individual capitula are centripetally developed, while they succeed one another on the main stem in a centrifugal or cymose order; in the Labiatæ the cymose axillary glomerules (which, occurring opposite to each other, form *verticillasters* or false whorls) are developed from below upwards, the main stem being indefinite, and they are often crowded together above so as to form a kind of compound spike.

The general facts of the morphology of the different forms of inflorescence are thus seen to be conformable to the laws ruling the development and ramification of the stem, as already explained.

The different modes of inflorescences often pass one into the other, and such inflorescence as scorpioid cymes may originate either in the manner above described, or, very rarely, by direct forking of the growing point [Warming]. The difference between a dichotomy of the growing point

and lateral ramification is not fundamental; and, again, where true dichotomy exists it is rare for the two divisions to be developed in the same manner. In some scorpioid cymes one division becomes a flower-bud, the other repeats the ramification of the axis.

Modifications of the Inflorescence.—In certain cases we have the normal condition of the inflorescence greatly disguised, as in *foliaceous peduncles*, and in cases of what is called *fasciation*, as also where the flower-stalks are apparently removed from their usual place by adhesion of various kinds and degrees.

In many kinds of *Cactus*, as already noticed (p. 38), the stem assumes more or less the outward aspect of a leaf; and when a flower springs from such a stem, it looks like an abnormal growth; but it is really produced from the terminal or axillary bud of an abortive branch. In the Butcher's-broom (*Ruscus*, fig. 155) the single branches or peduncles are flat leaf-like plates, and bear the flowers in the axils of little scales or reduced leaves which arise on the upper surface, seemingly from the midrib of a leaf; but these *foliaceous peduncles* grow from the axils of scale-like leaves (fig. 155 *). In *Xylophylla* (fig. 156) we find a *compound foliaceous peduncle*, consisting of a large leaf-like branch bearing numerous flowers on its margins, arising there in the axils of bracts.

Fig. 155.

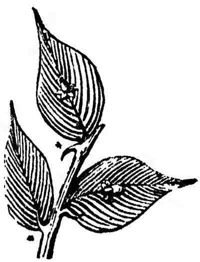


Fig. 156.

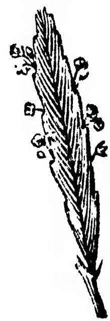


Fig. 155. Foliaceous peduncles of *aculeatus.*
Fig. 156. Foliaceous flowering branch of *Xylophylla.*

Fasciation is usually an abnormal condition, consisting of the development of a large number of buds in close approximation, and the consequent congenital fusion of a number of peduncles (or in some cases leafy shoots) into a solid mass, bearing the flowers on the borders. It produces the crest-like condition of the flower-stalk of the garden Cockscomb; and converts a paniculate inflorescence into a ribbon-like axis.

Adhesion, or want of separation of the peduncle from the leaf or bract, produces an appearance as if the flower sprang from the latter, as in the case of the Lime-tree. A similar union or, rather, lack of separation between the flower-stalk and the branch, the former being in such cases often raised above its normal level by the growth of the latter, produces *extraaxillary* inflorescence, as in some species of *Solanum*. Where the inflorescence is placed *opposite to a leaf*, as in the case of the Vine, &c., the inflorescence is in reality terminal (as may readily be seen in the young state); but as growth goes on it bends downwards into nearly a horizontal position, while the axillary bud next beneath it deve-

lops into a shoot which assumes a vertical direction, thus occupying the position of the inflorescence. Such branches are called by French botanists usurping branches. In a few cases absolute *partition of the growing point* has been observed—one division forming a tendril or an inflorescence, the other forming a new vegetative axis, as in *Vitis vulpina* observed by Warming.

Duration.—The inflorescence, like the leaf, varies in its duration. The staminal catkins of the Amentaceæ, such as the Oak, Hazel, Poplar, &c., fall off as soon as the pollen is discharged from the stamens, and they are called *caducous*. In many cases the inflorescence, or the individual peduncles, separate by a disarticulation when the fruit is ripe, as in the Apple, Cherry, &c.; the term *deciduous* is then applied. In the Rose we observe the dried-up fruit long remaining, like the cones of Firs, &c., after the seeds have become matured; these are *persistent*. Sometimes the peduncles undergo expansion during the ripening of the seeds, so as to form part of the fruit; such an inflorescence or peduncle is called *excrescent*. The Fig, the Pine-apple, and other fruits are formed of *excrescent inflorescences*; the Cashew-nut (*Anacardium*) has an *excrescent peduncle*.

Characters afforded by the Inflorescence.—For descriptive purposes the inflorescence must be treated as the ramifications of the stem, noting also the number of the flowers, their mode of expansion, and other peculiarities as explained in the foregoing sections.

Sect. 7. The Flower.

The Flower, the characteristic reproductive apparatus of the higher plants, consists of no new elements superadded to the fundamental organs of the vegetative regions, but is merely an assemblage of these organs modified in certain essential particulars so as to fit them for exercising new functions. A flower is a modified shoot, in which the internodes of the stem are seldom developed; while the leaves, arranged according to the general phyllotactic laws, are more or less different in form and texture, and have part of their tissues developed into more highly specialized products, distinguished both in anatomical and physiological characters from those associated with vegetative leaves.

The theory of the construction of the flower rests upon proofs derived from various sources, such as *teratology*, or the study of exceptional growths. The strongest confirmation of the views arising out of the observation of such cases is obtained by *comparative morphology*, by the *internal structure*, and by the *investigation of progressive development*, or "*organogeny*," which latter supplies a clue to the original ancestral form.

We may, in the first place, remark upon what is taught by the study of development. Flowers are common in which the organs stand in regular circles, and in which the organs of each circle agree in colour, size, and so on; but in many cases we find deviation from this regularity: the arrangement of the organs becomes changed, and the parts of particular circles become more or less different among themselves—as, for example, in the flowers of the Pea-tribe, of Labiatæ, &c. But when we examine the buds of these flowers in a very young state, we often, but not always, find the rudimentary organs regularly arranged, and, while in the state of cellular papillæ, agreeing exactly in all external characters. The subsequent irregularity is a result of special growth, for a special purpose, at a later epoch. In didynamous stamens, for example, the longer pair do not exceed the others until a late period of their development.

Transitional Forms.—The original uniformity and homogeneity of the organs of flowers are not always so completely lost in the maturation of the structures, that the different secondary types of organs, sepals, petals, &c. become entirely distinct. The study of comparative morphology reveals many cases of transition from one kind of organ to another, illustrating, in a very interesting manner, the doctrines of morphology.

In *Calycanthus floridus* and the Camellia the numerous pieces of the floral envelopes present a spiral arrangement, and it is impossible to find a distinct line of demarcation between the bracts, the calyx, and the corolla. In species of *Cornus* and *Euphorbia*, the coloured bracts of the involucre assume quite the aspect of a coloured calyx or corolla. In the White Water-lily (*Nymphæa*), a transition between sepals and petals is seen in the segments of the calyx, which are green outside and petaloid internally, while we have perfectly petaloid sepals in many flowers, as in Aconites, Larkspurs, &c., and particularly in the showy bulbous Monocotyledons commonly cultivated, *e. g.* the Lily (*Lilium*), Tulip, Crocus, &c.

In the Water-lily (*Nymphæa*) we observe a gradual transition between petals and stamens, the latter appearing first as petaloid plates, with anther-structure on the edges. In *Canna* it is the ordinary rule for the stamen to be a kind of petal bearing an anther-lobe on one upper edge. A more or less expanded petaloid state of the filament is not unusual, and in the Mistletoe the stamens are flat, leafy organs, with the pollen developed in the parenchyma of the inner face.

The stamens and pistils being so diametrically opposed in their physiological characters, we naturally do not expect to find any transition between these organs in normal flowers, though in monstrous developments such transitions are frequent.

Teratology.—The study of Teratology, the interpretation of exceptional growths by reference to laws of development more or less interfered with by external agency, is very instructive in regard to Morphology. In the exceptional products of nature or, still more, of art, we find illustrations of almost every possible kind of the general proposition above mentioned.

Phyllody.—Cases are not unfrequently observed where the entire flower is replaced by a fascicle of green leaves, especially in the Alpine Strawberry. In wet seasons it is not uncommon to find flowers of the

White Clover with more or fewer of the organs modified in this way, the pistil, one or more of the stamens, &c. appearing in the form of green leaves, occasionally compound and ternate, as on the stem below. In the Double Cherry of gardens, the place of the pistil is often occupied by a pair of green leaves; in the *Fraxinella* a circle of green leaves has been observed in the place of the ovary.

Substitution and Metamorphoses.—Almost all polypetalous flowers, and many gamopetalous, are capable of being "doubled" by cultivation, that is to say, the number of petals may be increased at the expense of the stamens, or of these and the pistils. For example, the Wild Rose has but five petals, and many stamens and pistils, but in our garden Roses the numerous stamens and pistils are often altogether replaced by petals. In many cases intermediately formed structures exist in such *double flowers*: in the double early Tulip, for example, we almost always find monstrous organs, half-petal and half-stamen, and even half-stamen and half-carpel; the same may be observed in double Pinks and Carnations. The ovules have been seen bearing pollen, while it is frequent to find the stamens bearing ovules. Illustrations obtained in this way might be multiplied *ad infinitum*. It should be observed, however, that in double flowers we frequently find not only all the essential organs replaced by petals, but an actual *multiplication* of the natural number of organs, as in Roses, Camellias, double Daffodils, &c.

Prolification.—In the last place, we may advert to the phenomena of the abnormal evolution of buds within the limits of flowers. Cultivated Roses sometimes send out a leafy shoot from the centre (prolification), the terminal bud not becoming arrested as is natural; on Apples and Pears we occasionally see one or two leaves growing out from the summit, from the same cause. In addition to this, the organs of the flower may assert their foliar nature by producing flower-buds in their *axils*, like stem-leaves. This has been observed in the case of the petals of *Celastrus scandens*, and also of *Clarkia elegans*, and occurs sometimes in garden Roses*.

These general observations will serve to show the essential *homology* of all the lateral organs of flowering plants with ordinary leaves, and more especially with the vaginal or leaf-scale portion of the leaves. The laws under which varieties of form &c. are produced within the limits of the flower all substantiate the same general principles.

Parts of the Flower.—The parts of flowers are:—the *perianth*, consisting of (1) the *sepals*, forming the *calyx*, (2) the *petals*, forming the *corolla*, and enclosing (3) the *stamens*, forming the *andrœcium*, and (4) the *carpels*, forming the *pistil* or *gynœcium*. That portion of the peduncle from which all these organs spring is called the *receptacle* or *thalamus*: it seldom has the internodes much developed, but is more or less expanded horizontally. It is sometimes convex or conical and elongated, and sometimes concave. When it forms a flattened

* A general review of these abnormal or unusual formations, and of the inferences that may be derived from them, is given in Dr. Masters' 'Vegetable Teratology,' published by the Ray Society.

surface above, its centre corresponds, of course, to the apex; and we may thus say that the above-named organs succeed each other from without inwards, or from below upwards.

The accompanying diagram of the floral whorls (fig. 157) illustrates the theoretical construction of a perfect and symmetrical flower. Here the internodes are imagined to be developed between the separate circles of the flower —an arrangement which does occasionally occur in nature, as in Capparids, Passion-flowers, &c.

Fig. 157.

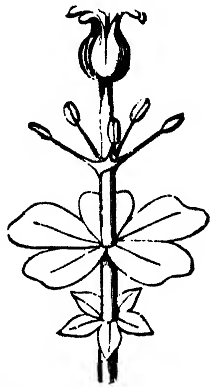


Diagram of the 4 circles of typical 5-merous flower, separated by internodes.

Anterior and Posterior portions of the Flower.—All axillary flowers arise in the angle between a bract or leaf and the stem; from this is taken the rule as to the relative position of organs in describing flowers. The side of the flower next the stem is the *upper* or *posterior* part, that next the bract the *anterior* or *lower*; and in the diagrams or ground-plans used to represent the construction of flowers, it is important to mark the places of the axis and the bract, the former being represented behind by a ○, the latter in front by an *x* or ‿, as in fig. 160.

Where flowers are solitary and *terminal* there is no proper back and front; but in plans of these, the position of the last leaf or bract, and specially of the bracteoles, should be shown. If, with a flower of four sepals, there is a pair of bracteoles, the two lowermost sepals are antero-posterior (fig. 167, p. 96); but if there are two pairs of bractlets, the two uppermost sepals are antero-posterior. When bracts are suppressed, as in the *Cruciferæ*, the position of the floral organs may be determined by their relation to the parent stem.

Arrangement of Parts.—The parts of flowers being phyllomes, their arrangement corresponds to that of stem-leaves. Sometimes they are truly whorled, while at other times, especially in the calyx and corolla, they are arranged in spiral cycles, and are *developed successively* on the $\frac{1}{3}$ or $\frac{2}{5}$ plan, but reduced into apparent whorls by the absence of internodes. Such flowers are called *acyclic*; and where some of the parts of the flower are arranged spirally and others in a verticillate manner, the term *hemicyclic* is given.

In such a calyx as that of the Rose, the sepals are imbricated on the $\frac{2}{5}$ plan (figs. 158–160). In the ternary floral envelopes of many Monocotyledons we find illustrations of the $\frac{1}{3}$ type. Sometimes the spiral

arrangement is still more evident, especially where there exist great numbers of a particular kind of organ, as in the mixed petals and stamens of *Nymphæa*, and the multiple pistils of *Ranunculus, Magnolia*, &c. In *Calycanthus* all the organs follow on in a continuous spiral.

In other cases the floral organs are *developed simultaneously*, when a true whorl is produced.

Fig. 158.

Fig. 159.

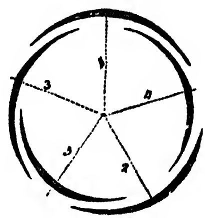


Fig. 158. Calyx of the Rose; the numbers indicate the sequence of the sepals from without inwards, or from below upwards.
Fig. 159. Section of the calyx of the Rose; the numbers as in the preceding figure.

Number of Parts.—According to the number of parts in a cycle or apparent whorl, these are distinguished as *dimerous* or *binary*,

Fig. 160.

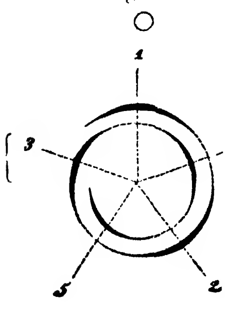


Fig. 161.

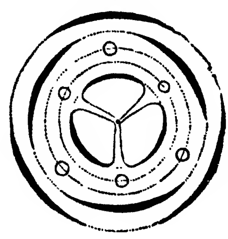


Fig. 160. Diagram of the $\frac{2}{5}$ spiral arrangement of the parts of the flower with bract and lateral bracteoles; O the situation of the axis.
Fig. 161. Diagram or ground-plan of the 3-merous flower of the Tulip.

trimerous or *ternary* (fig. 161), *tetramerous* or *quaternary*, and *pentamerous* or *quinary* (fig. 162). The ternary arrangement is by far the most common in the Monocotyledons, the quinary in the Dicotyledons.

Fig. 162.

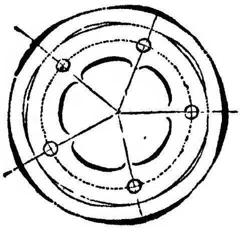


Diagram or ground-plan of the 5-merous flower of *Crassula*.

Most frequently the calyx and corolla have an equal number of parts; the relative number of organs is prone to increase in the staminal circles, and still more frequently to diminish in the carpellary whorl.

Alternation or Superposition.—In the majority of cases we find the organs of each successive whorl developed alternately with, and not super- or anteposed to, those of the preceding circle.

From this the whorls would appear to resemble the decussating whorls of true leaves, rather than regularly succeeding spiral cycles. We have seen that these decussating whorls are closely related to the spiral cycles (p. 48). Moreover we find in the very numerous cases of flowers with the organs imbricated in the bud, that the spiral arrangement is very evident, and the whorled appearance presents itself only after the expansion of the flower. Now, if the $\frac{1}{3}$ or $\frac{2}{5}$ cycles succeeded regularly, the organs of successive cycles should be superposed and not alternate, as indeed they sometimes are, e. g. *Sabia*. A. de Jussieu has supposed that the organs are arranged on the spiral $\frac{5}{13}$ type in all trimerous and pentamerous flowers with imbricated æstivation. Inspection of the diagrams in a former page (45) will show with how little displacement the organs of such flowers may be arranged on this type; and there is much probability that the alternation of spirally arranged cycles results from some such cause, while the alternation of organs in flowers with valvate æstivation is referable to the same laws as the decussation of whorls of leaves. The exceptional case of opposition of organs will be explained presently.

Typical Flower.—The typical flower in the diagrams (figs. 157, 162) consists of four circles of organs equal in size and number of parts, and with the parts regularly alternating. A flower thus presenting all the whorls is called *complete* or *eucyclic*; the organs in each circle being similar, it is *regular*; and the number of organs in each circle being the same, it is moreover *isomerous*.

Modifications.—Almost every kind of deviation and combination of deviations from this type are met with; but the modifications in the number, arrangement, and form of whorls or parts are referable to distinct causes, such as:—1. Alteration of the number of circles, or of the number of organs in the circles; this may arise either from *multiplication*, *chorisis*, *enation*, or *interposition*, or from *suppression* or *abortion* of parts. 2. Union of the organs; this

may be merely coalescence of the margins of organs of the same whorls (*cohesion*), or confluence of normally distinct whorls (*adhesion*). These so-called unions are generally the consequence of arrest of development, owing to which, parts usually separate in the adult condition remain *inseparate*. 3. Unequal growth or degree of adhesion in the organs of particular whorls, producing *irregularity*. 4. Irregular growth either of the receptacle, or production of outgrowths from various organs by *enation*. 5. Substitution of one organ by another (*metamorphosis*). 6. *Superposition*, where parts usually alternate are placed *opposite*, or, more correctly, are superposed the one to the other.

Dr. A. Gray has furnished an interesting illustration of these laws of modification, from a family (Crassulaceæ) in which different kinds of deviation occur together with examples of very symmetrical flowers. In *Crassula* (fig. 162) is found a symmetrical pentamerous flower, with five sepals, five petals, five stamens, and five pistils, all regularly alternating, and only slightly confluent at the base. In *Tillæa* some species have four, some only three organs in each whorl, but the flowers are still regular and symmetrical. In *Sedum* (Stonecrops, &c.) the flowers of some species are pentamerous, those of others tetramerous; but here the number of stamens is doubled by the introduction of an entirely new circle of these organs (*multiplication*). *Rochea* has the margins of its petals slightly *coherent*, while in *Grammanthes* the petals and sepals are respectively *coherent* more than halfway up. *Cotyledon* has *coherent* envelopes, and a double series (*multiplication*) of stamens as in *Sedum*, to which is added an *adherence* of the stamens to the tube of the corolla. In *Penthorum* the five styles are *coherent* firmly together below, while in some cases its petals are *suppressed*. In *Sempervivum* (Houseleek) the number of sepals, petals, and pistils varies in different species from six to twenty, and the stamens from twelve to forty.

Pleiotaxy, or multiplication of the number of whorls, is very common, especially as regards the stamens. In the trimerous flowers of Liliaceæ and Amaryllidaceæ there are six stamens standing in two circles of three. In the Poppy family the tetramerous circles are still more multiplied; and in the Rose, Buttercup, &c. we have further examples. When the number exceeds three or four circles of one kind of organ, the organs are said to be *indefinite* in number, and the verticillate arrangement becomes very indistinct in the opened flower. In the White Water-lily (*Nymphæa*) we have multiplication both of petaline and staminal circles; and in *Magnolia*, *Ranunculus*, &c. the pistils are much multiplied, exhibiting in these a distinctly spiral arrangement.

Multiplication of circles occurs abnormally in the *double flowers* of gardens, in which we often find far more organs than exist in the normal state, as in Daffodils and other flowers where the organs are naturally few

in number. The multiplication in this case is often due to *transverse chorisis*, the parts being superposed to each other. Each part so affected divides in a direction parallel to its surfaces into two or more parts. If the supernumerary part is an outgrowth from an already formed organ it is said to be formed by *enation*.

Pleiomery, or multiplication of the organs in particular whorls, occurs in a number of flowers, and depends on different causes. Sometimes the multiplication is effected by *collateral chorisis*, or division at right angles to the surfaces, a pair of stamens, for example, standing in place of one; in other cases the organ is divided parallel with the surfaces into an inner and outer part or into a fasciculus of organs. The cases of *collateral chorisis* are explained by the circumstance that the staminal leaf, in these cases, as in an ordinary lobed or compound stem-leaf, becomes subdivided and forms a *lobed* or *compound stamen*. In some flowers (as in many Ericaceæ) there are ten stamens in one whorl, while the sepals, petals, and carpels are pentamerous; in these cases the five additional stamens are formed subsequently to the others. This mode of multiplication of parts is called *interposition*.

Suppression, Abortion.—In describing the phenomena of diminution of the number of circles or organs of flowers, it is convenient to distinguish between *suppression* or total absence, and *abortion* or partial absence, when the organs are represented by imperfect or rudimentary structures.

A *complete* flower possesses a calyx and a corolla; the corolla, and even the calyx also, are wanting in some flowers, which are termed *incomplete*; when the corolla alone is wanting, the flower is *apetalous*; the term *naked* is occasionally applied to flowers without any floral envelopes.

The term *dichlamydeous*, having calyx and corolla, *monochlamydeous*, having calyx alone, and *achlamydeous*, destitute of floral envelopes, are used by some systematic botanists in place of the above. These conditions are not very secure bases for systematic divisions, since it is not uncommon to find apetalous plants in Orders having ordinarily complete flowers, as in the Caryophyllaceæ (*Sagina*, &c.): the apetalous condition, however, is constant in a large number of Orders, and familiar examples occur in the Nettle family, the Chenopodiaceæ, the Amaranths, &c. Achlamydeous flowers occur in the Willows, *Callitriche*, &c. Some flowers, then, are incomplete by abortion, in which case they are degenerate conditions of a more perfect type, or they are incomplete by suppression, when they are typically of a relative low degree of organization.

When *essential organs* (stamens and pistils) of both kinds are present, the flower is called *hermaphrodite* or *bisexual* (this condition is indicated by the sign ⚥). It must be remembered, how-

ever, that the term hermaphrodite is used in its morphological, not in its physiological significance, for many flowers hermaphrodite in structure are practically unisexual in function. In many plants one of the circles of essential organs is suppressed, so that a given flower has only stamens or only pistils; such flowers are termed *unisexual* or *diclinous*. The unisexual flowers are called respectively ***staminiferous*** or *male* (♂), and ***pistilliferous*** or *female* (♀). When flowers of both kinds occur on the same plant, this is called *monœcious* (Oak, Birch, Vegetable Marrow, &c.); when they are on distinct individuals, the plant is termed *diœcious* (Hop, Willow, Bryony, &c.); when, as in some cases, the imperfection results from a kind of regular abortion rather than total suppression, and the same plant or species exhibits at once staminate, pistillate, and hermaphrodite flowers, it is termed *polygamous* (*Parietaria*, many Palms, Maples, &c.). Some plants bear *neuter* flowers, destitute of both stamens and pistils: such is the case naturally with the outer florets of many Composites, and it is constantly seen in the garden Snowball (*Viburnum Opulus*) and *Hydrangea*.

The *diclinous* or *unisexual* condition is often typical and hereditary in certain families, such as Amentiferæ, &c.; but cases of diclinism occur not unfrequently in exceptional genera of families the majority of whose genera are bisexual, as in *Ruscus* among the Liliaceæ; or in exceptional species (by abortion), as in *Lychnis dioica*; sometimes it occurs by abortion in species normally possessed of perfect flowers, as in *Asparagus*.

Arrangement of Parts.—The suppression of an entire circle renders a flower unsymmetrical; for when the corolla is absent, we find the stamens commonly *superposed* to the segments of the preceding circle, as in *Chenopodium*; but this is in accordance with the normal type, as the stamens should be superposed to the sepals, the intermediate petals (here suppressed) alternating with both. Not unfrequently we find abortive organs, such as sterile filaments or "glands," of various kinds forming circles which restore the symmetry of apparently unsymmetrical flowers.

The cases of unsymmetrical conditions arising from the superposition of the organs of succeeding whorls are explained by some entirely by *suppression* or *abortion*; others more correctly refer some of these cases to *chorisis*. In *Geranium* we find alternating with the petals five little glands which must be regarded as abortive stamens, since in the succeeding whorl the five stamens alternate with these and stand in front of the petals; the five innermost and longer stamens, again, are superposed to the glands. In *Erodium* the outermost row is represented by glands, the second row by sterile filaments, and only five perfect stamens exist. Much the same conditions occur in the Linaceæ. On the ground of such facts as these,

the superposition of the stamens to the petals in Rhamnaceæ, the Vine, &c. has been explained by supposing a circle of stamens to have been suppressed between the petals and the existing stamens. Several recent writers attribute the stamens of Rhamnaceæ to chorisis of the petals with suppression of the true stamens, extending the same explanation to Byttneriaceæ and the Vine, where the true stamens are represented by sterile rudiments or glands *within* the existing stamens. In the Primrose, according to Pfeffer, the petals originate from the backs of the stamens, though in other cases it would seem that the stamen arises from the petal. In Primulaceæ the opposition of the stamens to the petals may, however, be a result of suppression; for in *Samolus* we find five lobes on the throat of the corolla alternating with the petals, while *Lysimachia ciliata* has five sterile filaments in addition to five perfect stamens.

Isomery, Anisomery.—Suppression or abortion of part of the organs of one or more circles is, as has been said, a very common cause of want of symmetry. This occurs by far most frequently in the carpellary circles, as might he expected from the organs being crowded on the point of the receptacle (multiplication of carpels occurring, on the other hand, where the receptacle is unusually developed); the stamens exhibit it not unfrequently; and it is observed also in the petaline whorl, and even in the calyx.

Symmetrical flowers may be either dimerous, trimerous, tetramerous, or pentamerous throughout; and when the organs are equal in all the circles the flowers are *isomerous*, if not so they are *anisomerous*: thus we have isomerous dimerous flowers in *Circæa* (fig. 163) and *Syringa* (fig. 164), isomerous pentamerous flowers in *Crassula* (fig. 162), before

Fig. 163.

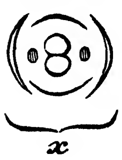


Fig. 164.

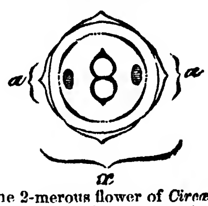


Fig. 165.

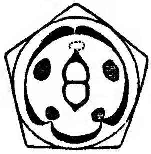


Fig. 163. Ground-plan of the 2-merous flower of *Circæa*: x represents the bract.
Fig. 164. Ground-plan of the Lilac, with 2-merous circles: x, the bract; a, a, bracteoles.
Fig. 165. Ground-plan of a labiate flower, with didynamous stamens; the posterior one (dotted) suppressed.

referred to; but, generally speaking, one or other of the whorls exhibits partial suppression.

It is rare to find the sepals *partially* suppressed: perhaps we may consider this to be the case as regards the limb of the sepals in such instances as the pappus of *Bidens*. The corolla exhibits partial suppression in some Leguminosæ, where, although the plan of the flowers of the order is pentamerous, in *Amorpha* only one petal exists; a transition towards

this occurs in other genera of the order, where, indeed, the four petals here suppressed are generally considerably smaller. In the Larkspurs (*Delphinium*) one petal is constantly suppressed, while the others are of irregular form; and in Aconite three out of the five petals are inconstant in their occurrence, being, even when present, mere petaloid scales.

The stamens are mostly *isomerous*, with either one, two, or more whorls, when the floral envelopes are regular, although there are well-known exceptions to this. The suppression or partial abortion of some of the stamens is most common where the flowers are irregular. This suppression is well seen in the irregular monopetalous Orders, where we find curiously graduated illustrations of the phenomenon. Thus, in the Scrophulariaceæ, belonging to the pentamerous type, there are usually but four stamens, but *Verbascum* has the fifth (not always fertile); *Pentstemon* has four perfect stamens and a sterile filament; and in *Scrophularia* the fifth is represented by a scale in the upperside of the corolla. In *Veronica* three are suppressed, and only two remain. In the Labiatæ (fig. 166), again, one stamen is ordinarily suppressed; not unfrequently two of these appear as sterile filaments; and in *Salvia, Monarda,* and other genera only two stamens exist.

Either *multiplication* or *suppression* is almost the rule in the carpellary circle, the isomerous condition being rather the exception. Six carpels, or a double circle, occur in the 3-merous flowers of *Triglochin* (fig. 166); and we have mentioned the occurrence of five carpels in the pentamerous flowers of *Crassula* and *Sedum*; in the nearly allied Saxifragaceæ the carpels are usually reduced to two. In Araliaceæ, *Aralia* has five carpels, different species of *Panax* three and two, while in the allied order

Fig. 166.

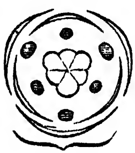


Fig. 167.

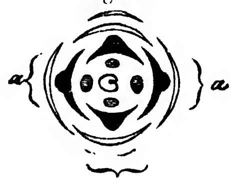


Fig. 166. 3-merous flower of *Triglochin maritimum*, with six carpels; *x* represents the bract.
Fig. 167. Ground-plan of *Epimedium*, with 2-merous circles and a solitary carpel; *a*, *a* are the bracteoles of the pedicel.

Umbelliferæ the number 2 is universal in the carpellary circle, although all the other circles remain pentamerous. In Rosaceæ we have almost every conceivable condition; for while multiplication takes place to a great extent in *Rosa*, *Fragaria*, and allied genera, the normal five carpels occur in *Spiræa* and the Pomaceous suborder; in *Agrimonia* the number is reduced to two; *Sanguisorba* has two or one; while in the Drupaceous suborder, in *Prunus* &c., only one carpel regularly exists, a condition which is the rule throughout the related extensive pentamerous order Leguminosæ. In Ranunculaceæ the number of carpels varies much. In Berberideæ the outer circles are 2-merous and the carpel is solitary (fig. 167). Suppression of a portion of the carpels is almost constantly

found in the monopetalous Orders, where we seldom have more than two.

Suppression of organs becomes exceedingly striking when associated with suppression of entire whorls. Thus in *Callitriche* the floral envelopes are wanting, and while the pistil indicates the tetramerous type, three stamens are suppressed, so that the perfect flowers consist of one stamen and one pistil, and the imperfect flowers often met with are composed respectively of a stamen and a pistil. The latter condition occurs also in the greatly reduced flowers of our native species of *Euphorbia*, in which the involucre encloses one naked female flower, consisting simply of a pistil, and a number of naked male flowers reduced to the condition of a single stamen (see Euphorbiaceæ).

A curious kind of regular suppression, not interfering with symmetry, is sometimes met with, where the typical pentamerous condition is replaced by the tetramerous, either in flowers of the same plant or on different individuals of the same species. Thus, in *Ruta*, in some species of *Sedum*, and some *Alsineæ*, the flowers have the organs sometimes in circles of fives and sometimes in circles of fours, without any other accompanying deviations from the character of the species.

Congenital Union or Inseparation.—Union of the organs of the flower consists either in *cohesion* of the parts of a whorl with their fellows, or in *adhesion* of organs of one whorl to those of another. Both occur in almost every possible degree. It must be borne in mind, however, that these terms are often applied to cases wherein there has really been no union of previously disunited organs, but a want of separation between parts originally uniform, but which in other cases become in process of growth disjoined.

Cohesion occurs in the calyx, producing what is called a *gamosepalous* or *synsepalous* calyx; also in the corolla rather less frequently, forming a *gamopetalous* or *sympetalous* corolla. With these terms are contrasted *polysepalous* and *polypetalous* (or *dialy-sep-petalous*), used to indicate that the sepals and petals are *distinct*, *i.e.* not coherent.

In the Vine the petals cohere above, while they are distinct below, and the flower opens by the separation of the corolla from the receptacle; the sepals of *Eschscholtzia* are entirely coherent, and fall off like a cap.

Union is less common among the stamens; but in some Orders they are coherent by their filaments into one piece (*monadelphous*), in others into two or more parcels (*diadelphous*). Such cases are usually due to a branching or lobing of the primary staminal leaves, and not to any real union of previously disconnected parts. Other plants have the anthers coherent (*syngenesious*), while the filaments are free; and in some diclinous flowers the stamens are united into a kind of column.

The carpels exhibit every degree of confluence, from a slight coherence at the base to a firm union by their sides, complete confluence of the ovary with the styles free, confluence of ovaries and styles in part or entirely with free stigmas, and complete confluence of ovaries, styles, and stigmas. In Asclepiadaceæ we have confluence of the styles, while the ovarian portions of the carpels are only slightly coherent.

The details regarding coherence will be treated of more conveniently in the chapters on the separate organs.

. may exist between the inner and outer circles of the floral envelopes, between petals and stamens, and between stamens and pistils, also between calyx, corolla and stamens with pistil free; or the calyx, corolla, and stamens may all adhere to the pistil. No case is known of adhesion of the three inner circles with a free calyx.

What is commonly termed *adhesion* is, as before explained, more strictly want of separation between parts which ordinarily become detached one from the other during growth.

Insertion.—The point of emergence of an organ is inappropriately called its *insertion*; and when an organ is not adherent to any other circle, but emerges directly from the receptacle, it is said to be *free.*

When the outer organs spring from the receptacle, they are called *hypogynous* (fig. 168), signifying below the pistil; if the stamens appear to adhere to the free tube of the calyx or corolla, they are said to be

Fig. 168.

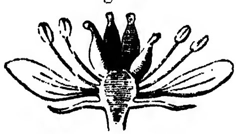


Fig. 169.

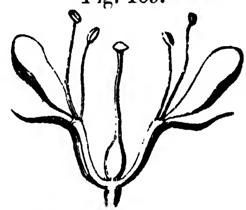


Fig. 168. Hypogynous flower of *Ranunculus*, in section.
Fig. 169. Perigynous flower of *Prunus*, in section.

perigynous (fig. 169); while if the tube of the calyx or receptacle is carried up and adherent to the sides of the pistil, the stamens become apparently *inserted* on the top of the ovary, and are then called *epigynous* (fig. 170).

Some other terms are used in reference to the insertion of the petals and stamens: thus, *thalamifloral*, or emerging from the receptacle, is synonymous with hypogynous (fig. 168); *calyciflоral*, indicating emergence from the throat of the calyx, may agree with either the perigynous (fig. 169) or epigynous (fig. 170) conditions; while *corollifloral*, emergence from the tube of the corolla, is a form of the perigynous insertion.

The terms *inferior* and *superior* are occasionally applied to the calyx, according as it is *free* (fig. 168) or *adherent* (fig. 170) to the pistil all the way up; occasionally it is half-superior (*Saxifraga*, fig. 171). The same terms are also applied to the pistil in the reversed sense to indicate the

same conditions: *i. e.* when the calyx is inferior, the free ovary is superior, and *vice versâ*.

The terms *perigynous*, &c., and *calycifloral*, &c. are in constant use and very convenient, but they may convey false notions as to actual structure. In the perigynous flowers of Rosaceæ, for example, such as those of *Fragaria*, *Geum*, &c., the stamens really rise from an expansion of the receptacle, forming the so-called throat of the calyx, and in *Rosa*, *Pyrus* (fig. 172), and other similar forms the carpels are really enclosed in an excavated receptacle or *receptacular tube*, from the upper edge of which sepals, petals, and stamens arise. In these cases the receptacle instead of lengthening into a conical extremity becomes tubular.

Fig. 170.

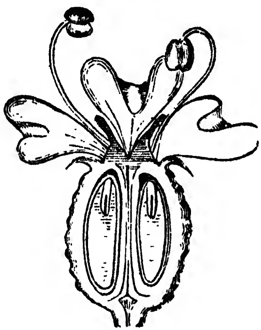


Fig. 171.

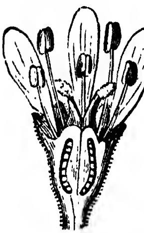


Fig. 172.

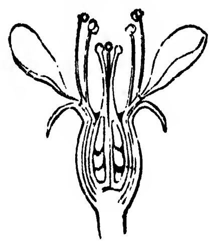


Fig. 170. Epigynous flower of an Umbellifer in section; pistil completely inferior.
Fig. 171. Flower of Saxifrage in section, with a partially adherent calyx and half-superior pistil.
Fig. 172. Flower of *Pyrus* in section; pistil inferior, calyx superior, corolla superior, stamens perigynous.

The adherence of stamens to pistils produces what is called the *gynandrous* condition, so remarkable a character of the Orchidaceæ and Asclepiadaceæ.

Irregular growth.—Irregularity of flowers arising from unequal *size*, different *form*, or unequal degree of *separation* of the organs or whorls is extremely common. Different form and size produce irregularity in the floral envelopes and stamens of many plants where these are free; and this is often associated with irregularity arising from suppression. The irregular union occurs alone, or is superadded to all the rest when the organs are coherent; this condition is oftenest found in the floral envelopes, in the stamens less frequently, and in the pistils perhaps not at all.

Irregular polypetalous flowers illustrating this point present themselves in Papilionaceous plants, in Fumariaceæ, Violaceæ, &c.; irregular polysepalous calyces occur in *Aconitum*, *Delphinium*, &c. Stamens are gene-

rally alike in the same circle; but in *didynamous* stamens (two long and two short) there is an exception to this. Irregular gamosepalous calyces and irregular gamopetalous corollas are met with in endless variety of forms, in the majority of which there is a tendency of the component organs of a whorl to associate together in two groups, front and back, so as to produce a bilabiate condition, as in the corollas of most Labiatæ and Scrophulariaceæ. Unequal degree of union of stamens produces the *diadelphous* condition of many Leguminosæ, and the still more irregular *polyadelphous* condition in the Orange. These points will be further explained in the next Sections.

It may be repeated here, that the deviations from irregularity falling under this head almost universally arise during the development of the bud from its originally regular rudiments.

Development of the Thalamus.—Most flowers have only very short or contracted internodes developed between the whorls: that is to say, the receptacle or thalamus is usually not lengthened. Exceptions occur to this, however; for in the Caper tribe we have long internodes between calyx, corolla, stamen, and pistil.

Fig. 173.

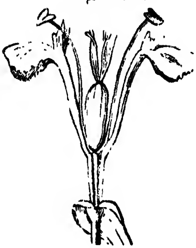


Fig. 174.

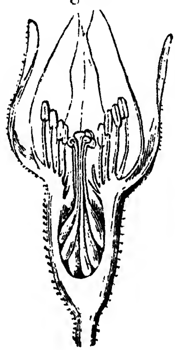


Fig. 175.

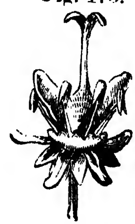


Fig. 173. Section of a flower of *Silene*, with an internode between the calyx (which is turned back) and the corolla.
Fig. 174. Section of the flower of the Rose; the pistils seated in a hollow receptacle.
Fig. 175. Flower of the Maple (*Acer*), with the petals removed, showing the stamens arising from an hypogynous "disk" or outgrowth from the receptacle.

In *Dianthus* and *Silene* (fig. 173) there is a short internode between the calyx and corolla, in *Gentiana* between the stamens and the pistil. In the Rose (fig. 174) the receptacle is expanded into a cup, from the inner walls of which the carpels arise; and in *Nelumbium* the carpels are immersed in a large fleshy receptacle. In many cases what is termed *calyx-tube* is in reality a tubular prolongation of the receptacle, from the edge of which the calyx, petals, and stamens arise. In the Pæony the receptacle is raised up into a kind of cup or "*disk*" round the carpels, in

P. Moutan enclosing them all but the stigmas: the apparently inferior position of the ovary of *Victoria* depends on the discoid development of the receptacle where the outer floral circles are inserted. A ring of similar nature, free from the ovary, occurs in *Alchemilla*. Another condition exists in the Mignonette (*Reseda*), where the cup-like or annular development of the receptacle is inside the floral envelopes, and forms a support to the stamens surrounding the ovary. This form of the "disk," which occurs also in *Acer* (fig. 175), must not be confounded with those depending on the presence of perfect or imperfect whorls of abortive floral organs. The epigynous disk of Umbelliferæ (fig. 170) and allied orders is probably a development of the receptacle, since the so-called adherent tube of the calyx is perhaps an excavated receptacle. In *Circæa*, and to a greater or less extent in other Onagraceæ, the epigynous process supporting the floral envelopes and stamens is prolonged into a tube above the inferior ovary, surrounding the long free style. Where organs are multiplied, we often find the thalamus lengthened into a conical or clavate body, to give room for the insertion, as with the pistils of *Ranunculus* (fig. 168), *Magnolia*, *Fragaria*, &c. In Geraniaceæ the receptacle is prolonged into a column in the centre of the confluent styles; and the same occurs to less extent in *Euphorbia*.

When a circle of organs is removed from its predecessor by a stalk-like internode, it is called *stipitate*. The column supporting the carpels of *Geranium* (p. 143, fig. 276), or those of Umbelliferæ, is termed a *carpophore*; the stalk of the ovary of *Gentiana* is a *gynophore*; a stalk above the corolla, supporting both stamens and pistils, as in Passion-flowers, is a *gynandrophore*. The form of the flower is dependent in many cases on the *obliquity* of the receptacle, as in Leguminosæ, *Aconitum*, *Delphinium*, and many other irregular flowers.

Enation, Substitution, Superposition.—The modifications arising from *enation* have been already alluded to; while those dependent on the *substitution* of one organ for another, as in many double flowers where the stamens are replaced by petals, demand only passing notice. *Superposition* arises from various causes, as from the abortion or suppression of a part that should come between and alternate with the superposed parts, or it may arise from *chorisis* or *enation*, or from true superposition of successive cycles, as in *Salvia*, and possibly by growth in the axil in the same way that a bud is axillary to a leaf.

Causes producing modifications.—The modifications met with in the construction of flowers may be dependent upon arrest, exaltation, or perversion of growth or of development, either separately or in conjunction. By growth is meant mere increase in bulk, by development the progressive change in the form and structure of organs (metamorphosis) which takes place in the course of their passage from the initial to the adult stage. By the action of the causes above mentioned, the parts of a plant vary in composition (simple or divided leaves, &c.), number (increased or diminished),

arrangement (spiral, opposite, or verticillate, &c.), freedom or union, form (regular or irregular), order of growth (consecutive, simultaneous, intercalary, definite, indefinite or interrupted, congenital or postcongenital, &c.).

These changes may be *congenital* and *hereditary*, and then common to all plants that have originated from a common ancestral type; or *acquired* or *adaptive*, when they have become manifest in order to fulfil certain special or individual requirements, or to put the plant in harmony with the circumstances under which it has to live. Thus the form, colour, and perfume of flowers are often in direct relation to the habits and structure of the insects which visit them for the sake of the honey, and whilst so engaged effect the fertilization of the flower in ways hereafter to be mentioned. It may thus be said that the form of the plant and its parts is dependent, 1st, on hereditary endowment, and 2nd, on adaptation to the work it has to do, the means it has of doing it, and the circumstances under which it must be accomplished. Sometimes from causes only imperfectly understood there is a *reversion* from a more complex or adult to a simpler or embryonic form, as when a petal or a stamen becomes leafy; and other cases of similar character may sometimes be explained hypothetically by assuming them to be reversions to an ancestral form.

Diagrams, Floral formulæ.—For purposes of ready comparison, and to avoid lengthy descriptions, diagrams or plans and floral formulæ are made use of.

A *diagram* is intended to show the number, arrangement, and relative position of the parts of the flower. Thus, fig. 162, p. 91, represents the diagram of a complete, regular, isomerous, pentamerous flower. Fig. 161, p. 90, shows a trimerous flower, with the parts in regular alternation. Diagrams of this kind are spoken of as empiric when they represent the actually existing state of the flower, while they are termed theoretical when the condition shown is that assumed or known to be the typical one, apart from the modifications brought about by abortion, chorisis, &c. Thus, fig. 165, p. 95, shows the usual condition in Labiates, where there are four stamens, the situation of the fifth, which is abortive, being shown by the dotted circle.

In place of diagrams, *floral formulæ* are sometimes made use of. These are constructed in various ways according to the views of various authors, though it would be convenient if uniformity of practice could prevail in this matter. The following illustrations will exemplify these formulæ: thus a regular pentamerous eucyclic flower may be represented thus:—

S 5 P 5 A 5 G 5;

the S representing the calyx of five sepals, P the corolla of five petals, A the andrœcium of five stamens, and G the gynæcium or pistil of five carpels, each whorl distinct from each other, and the parts of each individual whorl also distinct and free from cohesions or adhesions so-called. *In the instance given, the parts are assumed to be all in their proper alternate position; but this might be more clearly shown thus:—*

S 5 A 5
P 5 G 5

or more briefly thus:—

$$F\,5 = \begin{array}{cccc} S & & A & \\ & P & & G \end{array}$$

the F standing for flower.

In order to indicate cohesion a line or a bracket over the letters may be used, and a similar line placed vertically by the side of the letter may represent adhesion; thus the formula

$$\frown \qquad \frown$$

$$|\,{}^{\prime}P^{\backprime}A$$

may be taken to represent the flower of a Primrose, in which the five sepals are coherent, the five petals likewise coherent, the five stamens free among themselves, but superposed and adherent to the corolla, and lastly the five carpels coherent one with the other. The spiral or verticillate arrangements may also be indicated by similar devices, thus:—

$$\sim S\,\tfrac{2}{5}\,P\,5 \sim A\,\infty\,\overset{\frown}{G\,5}$$

would indicate a calyx of five sepals arranged spirally on the $\frac{2}{5}$ plan, a corolla of five petals verticillate, an andrœcium of numerous stamens arranged spirally, and a gynæcium or pistil of five coherent carpels, the sign $\sim$ indicating a spiral arrangement, and the sign ∞ always indicating an indefinite number of parts or too many to be readily counted *.

Sect. 8. The Floral Envelopes or Perianth.

Calyx and Corolla.—The floral envelopes of a typical flower consist of two circles of organs, forming the *calyx* and *corolla*. There is no fundamental difference between sepals and petals (the organs which compose these circles); and the only general definition that can be given is, that the outer circle (or, if only one circle exists, that circle) is the calyx; the corolla consists of the second circle (or sometimes of additional circles) of foliar organs intervening between the calyx and the stamens. In some few cases the perianth or floral envelopes are entirely wanting, as in many Aroids.

A Fig. 176. B

Calyx with epicalyx.
A. *Hibiscus* (Malvaceæ).
B. *Potentilla* (Rosaceæ).

The above definition of the calyx is liable to exception in rare cases; for in the Malvaceæ, the Dipsaceæ, and some Rosaceæ the true calyx

* For details relating to the morphology of the flower the student should consult Eichler's 'Blüthendiagramme,' Sachs's Text-Book, and Masters's 'Vegetable Teratology.' Reference should also be made to the account of the principal natural orders in the following pages, wherein the general principles of morphology are illustrated by reference to their particular application to different orders.

is double, that is, a circle of smaller organs, resembling sepals, or a tubular cup, stands outside the proper calyx, forming what is called an *epicalyx* (fig. 176). The ambiguity in these cases is removed by the existence of a well-developed coloured corolla inside the calyx.

The *epicalyx* of Malvaceæ, like that of Dipsaceæ, is perhaps to be regarded as an involucre of bracts. That of *Potentilla* (fig. 176, B) and allied genera is sometimes supposed to represent confluent lateral lobes or stipular appendages of the sepals.

Perianth.—The terms *perianth* or *perigone* are used in a *general* sense to signify all the floral envelopes, and are *specially* applied to instances where the distinctions between calyx and corolla are not apparent, *e. g.* when the sepals and petals are all petaloid, as in the Tulip, &c., and when they are all green and sepaloid, as in the Dock, &c. The words are also applied to the calyx in the Orders where it regularly exists alone, either in a sepaloid or petaloid condition, as in *Daphne* and the Monochlamydeous orders generally.

Æstivation.—The arrangement of the floral envelopes in the bud, the *æstivation* or *præfloration*, is a subject of great importance in systematic botany, as affording very regular characters in the majority of the natural orders.

The plans of æstivation given in illustrative works (fig. 177) are from horizontal sections of the bud just before it opens; and in cases where the sepals or petals are coherent below, the section is supposed to pass through the free lobes of the limb.

The æstivation of flower-buds agrees essentially with the vernation of leaf-buds (p. 72), especially as regards the folding of the individual organs; the sepals and petals may be *reclinate*, *conduplicate*, *plicate*, *convolute*, *involute* (a still further rolling-in rendering this *induplicate*), *revolute* (in excess becoming *reduplicate*); *circinate* as in the petals of *Hamamelis*, and an additional case is found in Poppies and some other flowers, where the petals are irregularly crumpled-up, or *corrugate*.

[Collectively the arrangement of the organs is either *imbricate*, *valvate*, or *open*. *Imbricate*.—The varieties of this kind are best seen in whorls of five, which furnish four distinct forms of æstivation, each being deducible from that which precedes it, by shifting the edge of one petal, as follows:—1. *Quincuncial*, or the $\frac{2}{5}$ plan (fig. 177, A). 2. *Half-imbricate* (B), which only differs from the last in that the 4th part overlaps the 2nd. 3. *Imbricate proper* (C), in which the 5th part overlaps the 3rd. 4. *Convolute* (D), in which the 3rd part overlaps the first. If convolute petals are twisted, they are called *contorted* (fig. 177, F). In other words, the axis of a median line down each petal is erect in the simply convolute, but spiral in the contorted.

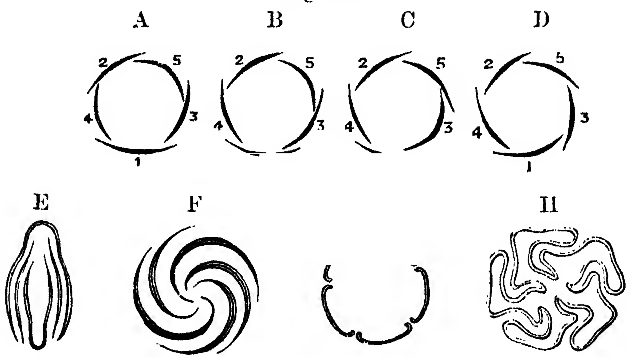
Imbricated whorls with four or three parts are usually either imbricate proper or convolute. Whorls with two parts are often *equitant* (fig. 125), as are the petals of Poppies; or *half-equitant*, as the sepals of Poppies, of which each part has one edge overlapping an edge of the other. These two conditions may be regarded as degraded forms of the imbricate proper and convolute respectively.

A special form of the half-imbricate is seen in the æstivation of papilionaceous corollas (fig. 177, E), and is named *vexillary*, from the posterior petal, which is called the *vexillum*, or "standard." The order of the petals is as follows:—The standard is No. 1; either keel-petal is No. 2; the wing-petal on the opposite side of the flower to the last is No. 3; the other wing No. 4; and the remaining keel-petal is No. 5. Thus No. 4 will be seen to overlap No. 2 (see figs. 191–193, p. 111).

The æstivation of the Snap-dragon (*Antirrhinum majus*) is called *cochlear*, but it is really half-imbricate.

When the organs are coherent at their margins they may become variously *plaited* or *plicate*, the portions sometimes assuming the contorted character, as in the corolla of the *Convolvulus* (fig. 177, H).

Fig. 177.



Æstivation of corollas.

A. Quincuncial. B. Half-imbricate. C. Imbricate. D. Convolute. (After G. Henslow.) E. Vexillary æstivation of the corolla of a Papilionaceous flower. F. Contorted æstivation of the corolla of *Malva*. G. Valvate æstivation of the corolla of *Vitis*. H. Plicate æstivation of the corolla of *Convolvulus*.

Valvate æstivation.—This kind of æstivation occurs when the margins meet but do not overlap (fig. 177, G). If the margins of the organs are rolled inwards they are *involute* or *induplicate* (fig. 127); if, on the other hand, they are rolled outwards, they are called *revolute* or *reduplicate*, in both of which cases the rolled borders only are in contact, and not the absolute margins.

Open.—This is also called "straight." The parts of the whorl, usually the calyx, are so rudimentary or arrested in growth, that they do not even meet, as in the *Umbelliferæ*, *Rubiaceæ*, &c. Hence this æstivation may be said to be *indeterminate.*—G. H.]

The calyx and corolla may both have the same æstivation, or they may be different; and their characters may hold good for all the species of a genus, as in *Hypericum*, in which the calyx is quincuncial and the corolla contorted, or even for all the genera of an order, as of Malvaceæ, in which the calyx is valvate and the corolla convolute or contorted; but it is very common for a species to have several varieties in different individual flowers, even on the same plant.

The direction of the spiral in imbricated æstivations is variable, often in the same plant: occasionally the direction changes in passing from the calyx to the corolla; at other times it remains the same; and this character is sometimes constant, in other cases very inconstant. In determining the direction of spirals, right-hand or left-hand, it is usual to suppose one's self standing in the axis of the organ; but many authors suppose themselves standing in front of it—for instance, in the place of the bract of a flower, which gives the exact opposite of the former; hence great confusion in the application of the terms *dextrorse* and *sinistrorse*.

Calyx.—The calyx is the outermost circle of the floral envelopes. It is composed of phyllomes or modifications of leaves, called *sepals*; according as the sepals are distinct or coherent, the calyx is termed *polysepalous* (or *dialysepalous*), or *monosepalous* (or *gamosepalous*).

The exceptions to the absolutely external position of the calyx have been pointed out.

The Sepals generally bear more or less resemblance to bracts, being attached by a broad base, seldom articulated, without any stalk, and of a green foliaceous texture; not unfrequently, however, their texture is of the coloured and delicate nature described as petaloid. They are usually *entire*, but the margins are sometimes cut, as in the Rose (fig. 158), and they are occasionally reduced to scale-like, or even feathery or hair-like processes. They are likewise subject to the production of pouches, spurs, &c., especially at the lower part, both when distinct and when coherent; and the apex is often more or less prolonged into a point or spine. Their mode of venation is usually like that of the sheath of the leaf.

Some confusion is liable to arise in the condition called a *superior* calyx, where the segments are totally free: if we suppose an adherent tube to exist below, such a calyx would be monosepalous; but the so-called calyx-tube is usually a cup-like receptacle, and the sepals originate or

become detached from the point where they appear to be inserted—for example, in Rosaceæ, Umbelliferæ, Cucurbitaceæ, Compositæ, &c.

Polysepalous Calyx.—In the polysepalous calyx, if the sepals are alike and symmetrically arranged, the calyx is *regular*; if some of the sepals are larger than others (*Helianthemum*, *Cheiranthus*, fig. 178) it becomes *irregular*; and this is still more the case when the sepals differ in form as well as size. Some of the most remarkable irregular forms of polysepalous calyx occur accompanied by a petaloid condition, as in *Aconitum* (fig. 179) and *Delphinium*.

The coloured calyces, both regular (*Fuchsia*) and irregular, may be easily mistaken for corollas; but they are known by their exterior position, and in some cases by the existence of a more or less perfect corolline circle within.

Direction.—The direction of sepals (whether distinct or partially coherent) is indicated by technical terms; thus they may be *erect*, *connivent* (the points turning in), *divergent*, or even *reflexed*.

Fig. 178.

Fig. 179.

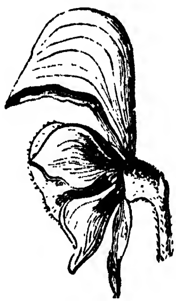


Fig. 180.

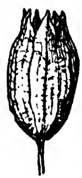


Fig. 178. Irregular polysepalous calyx of *Cheiranthus*. Two of the four sepals are dilated or "gibbous" at the base.
Fig. 179. Irregular polysepalous coloured calyx of *Aconitum Napellus*.
Fig. 180. Regular gamosepalous calyx of *Silene inflata*.

Parts of a Gamosepalous Calyx.—When the sepals are confluent or not separated, the *gamosepalous* calyx (fig. 180) is usually described as a whole. The part where the sepals are coherent or are still inseparate is the *tube*; the upper boundary of this is the *throat* (*faux*); and the free or spreading portion constitutes the *limb*—composed of *lobes* or *teeth* with intervening *sinuses* when the upper part of the sepals is more or less distinct; *entire* when the sepals are so completely confluent that the compound nature is not indicated by any teeth or fissures at the free edge.

It is necessary not to confound the *receptacular tube* with the *calyx-tube*

proper. An investigation of the course of development will show the difference between the two, and, generally speaking, the position of the petals and stamens; if the latter are *perigynous*, it is probable that the tube below is receptacular. The venation and internal structure will also serve as guides in this matter, inasmuch as the receptacular tube contains not only its own vascular bundles, but those of two or more verticils of flowers, and which are derived from the primary ones by subdivision.

Form.—The gamosepalous calyx is subject to the same kinds of modification as that in which the sepals are distinct. It is either *regular* or *irregular*.

Of the *regular* kinds we find a large number which present forms admitting of general technical names, such as *tubular* or *cylindrical, cup-shaped, infundibuliform* or funnel-shaped, *campanulate* or bell-shaped, *urceolate* when the tubular form is expanded below, *turbinate* or *top-shaped* when expanded above, *inflated* when the lateral view is oval or roundish with a narrow mouth (fig. 180), &c. In some species of *Campanula* there are regular appendages at the bottom of the sinuses between the teeth. In *Primula* and some other genera the tubular calyx is angular or plaited.

Calyces nearly resembling the above are rendered irregular either by a greater extent of disunion taking place between some of the sepals, the intervening fissures being so much deeper than the others that the teeth become associated in two sets, giving a *bilabiate* condition (fig. 181)—or by irregularities at the base, where a shallow pouch renders the calyx *gibbous* (fig. 178), a deeper one *saccate*, and a long narrow pouch forms what is called a *spur*. In *Pelargonium* this spur adheres to the peduncle. In some instances a tubular development of the receptacle or flower-stalk simulates the spur of the calyx.

Fig. 182.

Fig. 181.

Fig. 183.

Fig. 184.

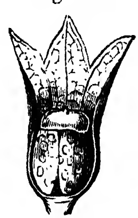


Fig. 181. Bilabiate calyx of *Salvia*.
Fig. 182. Floret of *Scabiosa*, the limb of the calyx replaced by bristles (*pappus*).
Fig. 183. Fruit of *Cichorium*, crowned by the persistent calyx represented by a circle of spines (*pappus*).
Fig. 184. Section of the persistent calyx, enclosing the ripe capsule, of *Hyoscyamus*.

The Pappus.—The free portion of the calyx of Compositæ, Dipsaceæ, and Valerianaceæ exhibits a very aberrant condition by appearing in the form of scales, bristles, or feathery or simple

hairs, constituting what is called the *pappus* (figs. 182, 183). In *Centranthus* the limb of the calyx is undeveloped when the flower opens, but expands during the ripening of the fruit into a crown of feathered processes. It is doubtful whether the pappus is not in some cases a series of mere epidermal growths or *trichomes*.

Duration.—The *duration* of the calyx varies much. In the Papaveraceæ it is *caducous*, falling off when the flower opens; if it falls with the corolla soon after fertilization of the ovules, it is *deciduous*; very frequently it is *persistent* during the ripening of the seeds, as in Labiatæ, some Solanaceæ (fig. 184), Compositæ (fig. 183), &c.; the upper part sometimes separates by a circular slit, leaving the base, as in *Datura Stramonium*; occasionally it grows during the maturation of the fruit, and is then *accrescent*, forming in *Physalis* and *Trifolium fragiferum*, for example, a vesicular envelope to the fruit. In the Marvel of Peru and other plants it is *marcescent*, remaining and growing into a firm envelope of the fruit.

Further details respecting the characters of the calyx are given under the head of the *Perianth*.

The Corolla.—The corolla is composed of all the leaf-like organs or floral envelopes situated between the calyx and the stamens; these are individually called *petals*, and may exist in one or more circles. Where many circles exist, the inner organs often become stunted or deformed, and more or less resemble barren filaments or abortive stamens (*Nymphæa*). Each petal, under ordinary circumstances, intervenes or alternates between two sepals.

The petals are either distinct, and then the corolla is called *dialypetalous* or *polypetalous*; or they are more or less coherent or inseparate, and the corolla is *gamopetalous*, *sympetalous*, or *monopetalous*.

When more than one circle of petals exists, the corolla is multiple or double; this is normal in certain plants, but is very liable to occur from transformation of stamens, &c., or from actual multiplication of whorls, as in cultivated flowers of the Rose, *Camellia*, *Ranunculus*, *Anemone*, &c. The petals are usually direct outgrowths from the thalamus, but sometimes they appear not to be autonomous parts but secondary outgrowths from the stamens, as in some Mallows, Primroses, &c.

The Petals.—Although petals frequently depart more than ordinary sepals from the character of true leaves in colour and texture, they present greater resemblance in some respects, since they frequently have a more or less developed petiolar region, which is sometimes of considerable length, at other times a mere thickened point; and they are commonly articulated to the receptacle. The petiolar portion of the petal is called the *claw* (*unguis*), the expanded portion the *limb* (*lamina*) (fig. 185). Petals are likewise more frequently cut at the margins, as in the fringed petals of Pinks and the laciniated petals of *Lychnis Flos-Cuculi*, or they are deeply

divided into lobes, as in many Caryophyllaceæ (fig. 186) and the pinnatifid petals of *Schizopetalum*, &c.

Fig. 185.

Fig. 186.

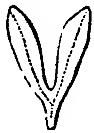


Fig. 187.

Fig. 185. Petal of *Dianthus*, fringed and stalked. Fig. 186. Bilobed petal of *Alsine media*. Fig. 187. Spurred petal of *Aquilegia*.

Forms of Petals.—The forms of petals resemble many of those indicated for simple true leaves; in addition to which others occur presenting curved surfaces: these are called simply *concave*, *navicular* or boat-shaped, *cochleariform* or shaped like the bowl of a spoon, &c.; or they may have basal pouches, and be *gibbous*, *saccate*, or *spurred* (fig. 187). Others have peculiar appendages above, such as the *crests* in *Polygala* and the *strap-like* inflexed points in the petals of the Umbelliferæ.

The term *nectary* is vaguely employed to indicate certain structures of varying character intermediate in position between the petals and the stamens, and different in aspect from both.

Petals are ordinarily of delicate structure and coloured, whence we derive the term *petaloid*; but they vary in texture from a membranaceous to a thick and fleshy condition, such as we see in *Magnolia*, *Nymphæa*, &c.

Polypetalous Corollas are *regular* when the petals are equal and symmetrically arranged; the individual petals may be themselves either symmetrical or oblique, provided they are all alike.

Some of them have received special names, such as:—the *rosaceous*, where there are five spreading petals; the *liliaceous*, where six petals spread gradually from a funnel-shaped origin; *caryophyllaceous*, where five petals have long erect claws from which the limbs turn off at a sharp angle; *cruciform*, where four such long-clawed petals with horizontal limbs stand in the form of a cross, as in the Wallflower, &c. Slight degrees of *irregularity* arise from some petals growing larger than others, as in the case of the outer petals of the outer flowers of the corymbs of *Iberis*, those of the umbels of *Umbelliferæ*, &c.; but more striking irregularity results from unlikeness of the petals and disturbance of symmetry in their insertion or point of emergence. The imperfect corolla of

Aconite (fig. 188) is an example of this; and a still more important case occurs in the *papilionaceous* corolla of *Leguminosæ* (figs. 191–193), which is composed of five petals, of which the posterior, the *vexillum* (fig. 192, *a*) or standard, the largest, usually symmetrical in form, is placed transversely; the two lateral (fig. 192, *b*, *b*), mostly oblique in form and small, forming the *alæ* or wings, stand right and left, with the edges fore and aft; and the two anterior (fig. 192, *c*, *c*), also small and oblique, often coherent in front, and forming the *carina* or *keel*, also stand with their edges forward.

Fig. 188.

Fig. 189.

Fig. 190.

Fig. 188. Flower of *Aconitum* with the sepals removed, showing the two hammer-headed posterior petals (or nectaries), with lateral and anterior scale-like petals, outside the numerous stamens.
Fig. 189. Bilabiate scroll-like petal (or nectary) of *Helleborus*.
Fig. 190. Floret of Composite, with inferior ovary surmounted by scaly pappus and tubular corolla.

Examples occur in the large order Leguminosæ of almost every modification of the papilionaceous corolla, approaching to regularity in *Baptisia* for instance, and still more in *Cassia*. Irregular corollas exist also in the Fumariaceæ, in *Viola*, Balsaminaceæ, *Pelargonium*, *Tropæolum*, and very many other plants.

Fig. 192.

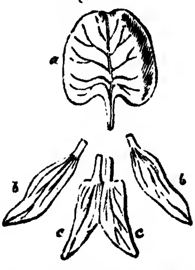


Fig. 191.

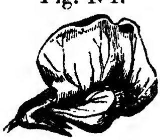


Fig. 193.

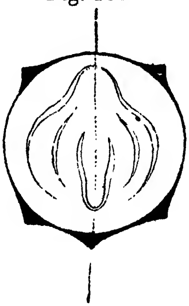


Fig. 191. Papilionaceous corolla of Pea.
Fig. 192. The separated petals: *a*, vexillum; *b*, *b*, alæ; *c*, *c*, carina.
Fig. 193. Ground-plan of floral envelopes, showing the coherent sepals and æstivation of the petals. The central line shows that the flower may be symmetrically divided into two equal halves.

Gamopetalous Corollas have a *tube*, *throat*, and *limb* like the gamosepalous calyx; and similar terms are used to indicate the more common *regular* forms, such as *tubular* (fig. 190), *campanulate* (fig. 194), *funnel-shaped* or *infundibuliform* (fig. 195), *urceolate* (fig. 196), &c., a few others being requisite for the corolla, more especially such as *rotate*, when the tube is extremely short and the limb spreads at a right angle (*Anagallis*), *hypocrateriform* or *salver-shaped* when a similar limb turns off from a long slender tube (*Jasminum*, *Phlox*) (fig. 197), &c.

Irregular gamopetalous corollas often furnish important systematic characters; and several of the forms or classes of forms have special technical names.

The *ligulate* corolla is tubular at the base; but disunion soon occurring at one sinus, the limb is turned off to one side in the shape of a flat ribbon or strap, on the margin of which occur more or less distinct teeth

Fig. 194.

Fig. 195.

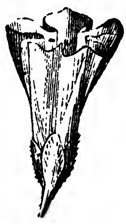


Fig. 196.

Fig. 197.

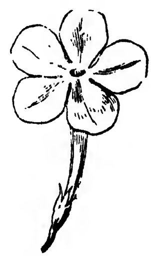


Fig. 194. Campanulate corolla of a Gentian.
Fig. 195. Funnel-shaped corolla of *Convolvulus*.
Fig. 196. Urceolate corolla of a Heath.
Fig. 197. Salver-shaped corolla of *Phlox*.

indicating the five component petals (fig. 198); this is especially found in the ray *florets* of Compositæ: a modification with the tube and limb wider in proportion to the length occurs in Lobeliaceæ. The *labiate* or *bilabiate* corolla of the Labiatæ (fig. 199) is formed by the two upper petals of the limb, which are scarcely at all separated, and stand apart from the three lower or anterior petals, which also are only partially separated, forming a lower lip opposite the upper one and projecting forward from the *throat* of the corolla: sometimes the upper lip is concave, and is then termed *galeate*, or helmet-like; in other cases (*Ajuga*) it is almost abortive.

Almost every modification of this form occurs in the Labiatæ, approaching to an almost regular tubular corolla in *Mentha*. This form occurs also in the florets of some Compositæ and in those of various Dipsaceæ, where, however, the upper lip is 3-lobed and the lower 2-lobed; in the Honeysuckle the upper lip contains four petals, and the lower is formed by a solitary one. *Veronica* has an irregular corolla intermediate between *bilabiate* and *rotate* (fig. 200).

The *personate* or *mask-like* corolla is rather indefinite in form: the type of it occurs in *Antirrhinum* (fig. 201), which approaches the *labiate* form; but the throat is closed by a gibbous projection (forming the *palate*), giving the front view the appearance of a mask with a broad-lipped mouth.

Fig. 198.

Fig. 199.

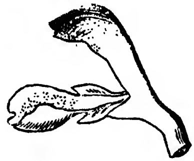


Fig. 200.

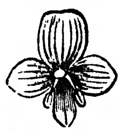


Fig. 201.

Fig. 198. Ligulate corolla of Composite, with "inferior" ovary and scaly pappus.
Fig. 199. Bilabiate corolla of *Salvia*, of five united irregular petals.
Fig. 200. Corolla of *Veronica*, bilabiate in structure, but the four segments spreading like a rotate corolla, and with two stamens.
Fig. 201. Personate corolla of *Antirrhinum*.

This is accompanied by a similar *gibbous* condition of the base of the tube in *Antirrhinum*, and by a spur in the same situation in *Linaria*. Aberrant forms of this type occur in *Calceolaria* (fig. 202), *Utricularia*

Fig. 202.

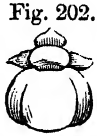


Fig. 203.

Fig. 204.

Fig. 205.

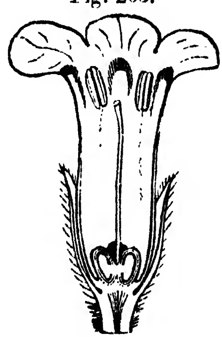


Fig. 202. Personate corolla of *Calceolaria*.
Fig. 203. Personate corolla of *Utricularia*.
Fig. 204. Petals of *Lychnis*, with scales at junction of stalk and blade.
Fig. 205. Section of a flower of a Boraginaceous plant, showing scales in the throat, between the stamens, superposed to the petals.

(fig. 203); and it runs into the *labiate* form by such corollas as those of *Melampyrum* &c., becoming tubular in *Digitalis*. Forms allied to this occur commonly in Bignoniaceæ, Gesneraceæ, Acanthaceæ, &c.

When the throat of a bilabiate or irregularly lobed tubular corolla is widely opened, it is called *ringent* or gaping.

Outgrowths from Petals.—Petals when distinct sometimes exhibit appendages on the inner face which have been interpreted as stipulary, as in *Lychnis* (fig. 204); in *Ranunculus* we find a minute *scale* at the base, and in *Parnassia* a largish scale, simple or divided, and of glandular character. In gamopetalous corollas we often find a *circle* of *scales* in the throat, either free or confluent into what is called a *coronet* (*corona*), sometimes developed so far as to produce a long tube projecting from the throat. In other cases there is simply a ring of hairs in the throat (*Mentha*, &c.). In most cases the scales are in front of the lobes of the corolla (fig. 205), rarely alternate and opposite to the sinuses.

Examples of circles of scales in the throat occur especially in the Boraginaceæ (*Myosotis*, *Symphytum*, &c.), in *Cuscuta*, &c. In *Narcissus poëticus* and other species the corona is a complete ring, while in *N. pseudo-narcissus* (the Daffodil) it forms the deep yellow tube projecting from the centre. Some authors attribute these structures to *chorisis*, others regard them as representing a circle of regular stamens in an abortive condition; and the alternate scales of *Samolus* may represent an abortive circle of stamens, as this would restore the symmetry of the flower. Usually, however, they are mere outgrowths from the petals, formed by *enation* at a late stage of development.

These structures, by a confusion of terms, have been called *nectaries* and nectariferous scales. The terms *scale* and *coronet* are more exact and convenient.

Fig. 206.

Opening flower of the Vine. The petals, cohering by their tips, fall off in one star - shaped piece.

Duration.—The corolla is *caducous*, *deciduous*, or *persistent*, like the calyx. Occasionally it falls away in part by a circular slit, as in *Orobanche* and *Rhinanthus*.

In *Vitis* the caducous *corolla* separates from the receptacle at the bases of the petals, which cohere above and fall off like a little star when the flower opens (fig. 206). The corolla is mostly *deciduous*; it is persistent in *Campanula*.

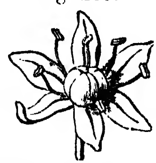
In withering, the petals are sometimes closed (*occlusa*), as in *Echeveria*, spreading as in *Boussingaultia*, *reflexed* as in *Begonia*, *crisped* as in *Pavia*, pulpy as in *Tradescantia*, *circinate* as in *Capparis*, *recircinate* as in *Mesembryanthemum*, and *conduplicate* as in some species of *Ornithogalum*.

The Perianth, in a special sense (see p. 104), consists of the floral envelopes when composed of two circles of similar organs, so that, except in position, there is no difference to be seen between

calyx and corolla, as in the Tulip; or of one circle, then always called a calyx whatever its colour, as in Monochlamydeous flowers.

A large number of the Monocotyledonous orders possess a *petaloid perianth*; that is, there are two circles of petaloid organs, which, from their resemblance, or actual coherence, have the appearance of a single hexamerous whorl. This perianth may be *regular* (fig. 207) or *irregular*, like the normal calyx and corolla; it may be *polyphyllous* or *gamophyllous*; and the outer circle may differ to some extent from the inner in form, size, and colour, without other irregularity. The forms are described by the same terms as those used for the calyx and corolla.

Fig. 207.



Regular 6-merous petaloid perianth of *Allium*, enclosing six hypogynous stamens and a central 3-lobed pistil with a single style.

We have a regular polyphyllous perianth in the Tulip and Lily; a regular gamophyllous perianth in *Hemerocallis*, *Convallaria*, *Tamus*, &c.; a regular polyphyllous perianth with unlike circles in *Iris*; and irregular polyphyllous perianths in Zingiberaceæ, Orchidaceæ, &c.

Perianth of Orchids.—The irregular perianth of Orchidaceæ (figs. 208 & 209) requires especial mention, as the Order is very large and the characters of the perianth peculiar. There are three outer organs (*a, a, a*), more or less alike, and usually smaller than the inner; of the inner, the lateral (*b, b*) are smaller than the posterior (*b'*), called the lip (or *labellum*), which is often excessively developed, and even divided into regions which receive separate names; in many of our native Orchids it possesses a spur (fig. 208, *b**).

Fig. 208.

Fig. 209.

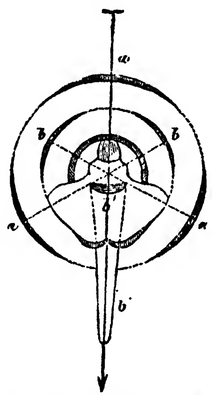


Fig. 210.

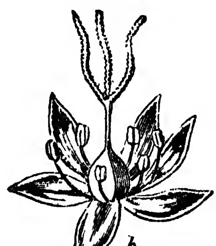


Fig. 208. Flower of an Orchis, seen in its natural position, where, owing to the twisting of the inferior ovary, the anterior or inferior part is above and the posterior below. *a, a, a,* represent the outer parts of the perianth or petals; *b, b,* the lateral petals; *b'*, the labellum, prolonged behind at the base into a spur, *b**.

Fig. 209. Ground-plan of the flower, with the same references.

Fig. 210. Flower of *Luzula*: *b*, the 6-merous scaly perianth, surrounding six hypogynous stamens and a central 3-cornered pistil with a single style and three stigmas.

Perianth of Palms.—The perianth of the Palms, of Juncaceæ (fig. 210), and other Monocotyledons is composed of scale-like, fleshy or membranous organs, either free or confluent, approaching to the condition found in the Glumiferæ.

Monochlamydeous Perianth.—The perianth of the Monochlamydeous Dicotyledons is very varied in form, texture, and colour. It may be *gamophyllous* or *polyphyllous*, and then *regular* (fig. 211) or *irregular* (fig. 212), and, moreover, *petaloid* or *sepaloid*. It is reduced to the lowest state in the Poplar (fig. 213), where it is a mere membranous cup; and it is absent in the allied genus *Salix*, as also in the Ash (fig. 214), which are therefore *achlamydeous*.

Fig. 211.

Fig. 213.

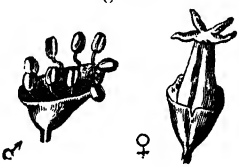


Fig. 212.

Fig. 211. Regular perianth of *Asarum*.
Fig. 212. Irregular perianth of *Aristolochia Clematitis*.
Fig. 213. Flower of the Poplar: ♂, from a male catkin; ♀, from a female catkin; each with a cup-shaped perianth.

A gamophyllous, coloured, regular perianth exists in Thymelaceæ (*Daphne*); the dull-coloured gamophyllous perianth of *Aristolochia* is irregular (fig. 212). The gamophyllous sepaloid perianths of *Ulmus* and *Castanea* (figs. 215, 216) &c. are regular: the polyphyllous sepaloid perianth of Urticaceæ is also regular. In *Polygonum*, the regular gamophyllous perianth is partially petaloid, while, in the same order, *Rumex* and *Rheum* have a double circle of unequal, wholly sepaloid organs.

Glumaceous Perianth.—The perianth of the Glumiferous Monocotyledons requires special mention.

In the Grasses, as already mentioned, the flowers are borne in *spikelets*, associated in spikes, or panicles. A spikelet of the Oat, for example (fig. 217), exhibits at its base a pair of green membranous bracts, the *glumes* (*a*, *a*) more or less enclosing all the inner parts: these are regarded as bracts, or *spathes*; and within them are found one, two, or more flowers. The flowers succeed one another alternately on a *rachis*; and each is invested by a bract resembling the glumes, called the *flowering glume* or the *outer palea* (figs. 217–219, *b*): within this is an inner scale

forked at the top, and often with two distinct principal ribs; hence it is regarded as composed of two confluent scales. This is called the palea or the *inner palea.* These scales often bear a projecting bristle (*awn,*

Fig. 215.

Fig. 214.

Fig. 216.

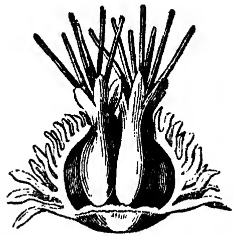


Fig. 214. Naked flower of the Ash (*Fraxinus excelsior*).
Fig. 215. Flower of the Elm (*Ulmus*), with a regular 5-toothed perianth.
Fig. 216. Involucre or young cupule of the Chestnut (*Castanea vesca*), with two female flowers, each having a regular perianth.

arista) at the top or on the back (fig. 218, *b**). Within the pale (fig. 219) occur two or in some Grasses three little hypogynous scales (*lodiculæ*, *x*, *x*), corresponding to petals; and to them succeed the stamens and pistil.

Fig. 217.

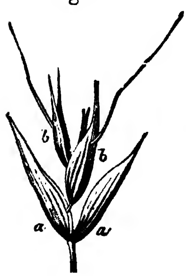


Fig. 219.

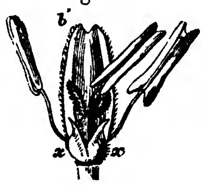


Fig. 218.

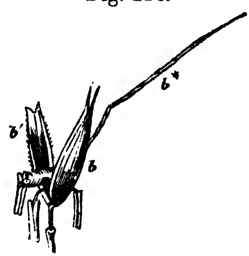


Fig. 217. Spikelet of the Oat: *a*, *a*, glumes; *b*, *b*, the flowering glumes or outer pales of the two florets.
Fig.
Fig.

The hypogynous scales are three in number in *Stipa*, restoring the symmetry. The upper glume is sometimes abortive, as in *Lolium*, while in *Nardus* both are absent. In *Alopecurus* only one pale is developed. The spikelet often contains one or more imperfect flowers.

The perianth of Cyperaceæ, where it exists, presents a still simpler

condition, analogous to that in the Amentiferous Dicotyledons, and in some cases is abortive. In *Scirpus* (fig. 220) it consists of a circle of bristles; in *Eriophorum* it is a tuft of hairs, which grow out into a "lock" of cotton as the fruit ripens. In *Carex* (fig. 221) there is an urceolate or

Fig. 220.

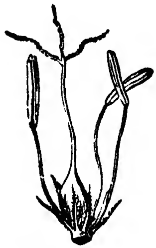


Fig. 221.

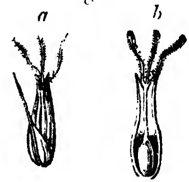


Fig. 220. Flower of *Scirpus*, the essential organs surrounded by a circle of bristles.
Fig. 221. Female flower of *Carex*: *a*, the *perigynium*, or perianth, in the axil of a bract; *b*, the tubular *perigynium* cut open vertically, to show how it surrounds the pistil.

inflated tubular *perigynium* or *utriculus* surrounding the pistil of the fertile or female flower, which stands in the axil of a bract, and which is itself composed of the union of two scales or bracteoles. *Cyperus*, *Cladium*, &c. have the essential organs naked in the axil of a bract.

Sect. 9. The Essential Organs of Flowers.

The essential organs of flowers consist of an *andrœcium* or assemblage of *stamens*, and of a *gynœcium* or *pistil* consisting of *carpels* with their contained ovules. The andrœcium and the gynæcium are both present in *perfect* flowers, although these latter may be *incomplete*, from the absence of floral envelopes. In *diclinous* or *unisexual* flowers the stamens or pistils exist alone, and the flowers are consequently *imperfect*.

Organs *morphologically* intermediate between petals and stamens occur, not only normally, as in the flowers of *Nymphæa*, but such structures are very common in monstrous double flowers, bearing anthers or polliniferous lobes upon the borders of petals. The morphological connexion is also kept up by the existence of sterile filaments or stamen-stalks, which, like the filaments of perfect stamens, may exhibit a *petaloid* character.

In monstrous flowers sometimes imperfect organs present themselves, partaking of the outward characters both of stamens and carpels.

The Disk.—Abortive organs, referable either to the corolline or the staminal circles or excrescences therefrom, have been already referred to; but it is desirable to notice more particularly the conditions of those structures which are commonly described under the name of *disk* (see p. 100).

The simplest state is that of one or more glandular papillæ upon the receptacle, as in the Cruciferæ. In the Crassulaceæ (*Sedum*, *Sempervivum*) we find a circle of glandular bodies outside the carpels and between these and the stamens. In *Cobæa*, the Vine, and other flowers there is a five-lobed hypogynous disk, the stamens being inserted outside or between the lobes. In *Citrus* (fig. 222) the disk forms a perfect ring round the ovary. In *Gaultheria* there is a double circle of scales between the stamens and the ovary. On the other hand, in *Vinca* there are two glands, alternating with the two carpels of the ovary. The study of these structures is very interesting in regard to the reduction of irregular flowers to regular types. Some of the structures are rudimentary petals or stamens; and in other cases they are referable to developments of the receptacle or *torus* itself (p. 100).

Fig. 222.

Flower of *Citrus* with the petals and stamens removed, showing the calyx and the annular disk surrounding the ovary. In this case the disk is an outgrowth from the receptacle.

The Andrœcium.

The Stamens taken collectively form the *Andrœcium*. The essential character of a stamen is, that it is that organ in which are formed the *pollen-grains*, the bodies by means of which the fertilization of the ovules is effected. A completely developed stamen (fig. 223) exhibits two principal regions, the *filament* or stalk (*a*), corresponding to the petiole of a leaf, or, as Clos thinks, to the midrib of a petal; and the *anther* (*b*), corresponding to the blade of a leaf. The anther is a hollow case containing pollen, and is therefore the only essential part of the organ: the filament may be wanting or merely rudimentary; and the anther then remains *sessile*, like a leaf-blade when the petiole is not developed. The normal position of the stamens is between the petals and the pistil; each stamen, under ordinary circumstances, intervenes between two petals or is *alternate* with them, and therefore *superposed* or opposite to a *sepal*. In *Naias* and *Typha* it is supposed that the stamen is axial and not foliar.

The base of the filament, or of the so-called sessile anther, is usually *articulated* to the receptacle when these organs are *free*; but this condition is more or less disguised when the stamens are adherent to or inseparate from the calyx, corolla, or ovary.

Staminodes or sterile filaments, *i.e.* such as are devoid of anthers, occur in many flowers in regular circles; and not unfrequently one or more stamens exist in this condition in unsymmetrical flowers. Sometimes these staminodia are reduced to mere *scales*, as in the odd stamen of *Scrophularia* (fig. 224), or to glandular papillæ, as in the flowers of many Cruciferæ.

Filament.—The filament, in its usual condition, is a slender thread-like stalk to the anther, and in this state is termed *filiform.* Sometimes it is almost hair-like, and incapable of supporting the

Fig. 223.

Fig. 224.

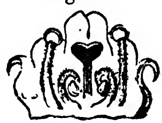


Fig. 225.

Fig. 226.

Fig. 223. A stamen: *a*, the filament; *b*, the anther.
Fig. 224. Corolla of *Scrophularia* laid open, showing the four didynamous stamens and the posterior barren one, or staminode.
Fig. 225. Stamen of *Allium*, with a trifid filament.
Fig. 226. Stamen of *Paris quadrifolia* with prolonged connective.

weight of the anther, when it is *capillary*, as in the Grasses; while it is still more frequently thick at the base, diminishing gradually upwards, so as to become *awl-shaped* or *subulate.* In a few instances (*Urtica*) it is *moniliform*, or like a row of beads. In other cases it is more or less expanded into a *petaloid* condition, as in *Erodium*; in *Campanula* it is expanded in this manner at the base. *Ornithogalum* has the filament *dilated* in this way throughout. The dilated filament sometimes exhibits *divisions*: in *Crambe* it is forked at the summit, the anther standing on one point; in *Allium* (fig. 225), *Alyssum calycinum*, *Ornithogalum nutans*, &c. the filament terminates in three teeth, the middle one bearing the anther; and in *Allium sativum* one of the lateral teeth forms a kind of tendril.

Branched Stamens.—In some plants, as in Mallows, some Myrtaceæ, *Hypericum*, &c., the stamens are very numerous and are arranged in fascicles. The study of the development of these fascicles shows that they are originally single organs, which become subsequently divided or branched, so that the fascicle of stamens in such a case may be compared to a divided or compound leaf. Some of the divisions may be petaloid and sterile, others antheriferous.

Appendages of other kinds are also met with, such as a pair of *glandular processes*, standing like stipules near the base, in Lauraceæ (fig. 233), a single *spur* in Rosemary; while in *Borago* the

filament appears to arise on the face of a scale-like body, and in *Simaba* and *Larrea* it stands at the back of an analogous scale.

The scale-like organs situated at the base of filaments, or connected with fascicles of stamens (*Tiliaceæ*), are by some regarded as furnishing evidence for the doctrine of *chorisis*; but they are more probably merely barren lobes of compound stamens.

The Anther—its parts.—The anther has a typical form, which is subject to very great modification in different cases. It corresponds to the microsporangium of some of the higher Cryptogams. A *regular* anther (fig. 223, *b*) is an oblong body, divided perpendicularly into two *lobes*; the division is usually marked by a furrow on the *face*, and a ridge on the *back* (or *dorsum*). The central region, which is solid and represents the midrib of a leaf, is called the *connective*; the *lobes* are hollow dilatations of the lamina, and contain the *pollen*. At each border, usually rather toward the *face*, is often to be seen a vertical line, called the *suture*, indicating the place where one class of anthers split open to discharge the pollen.

Attachment to the Filament.—The anther is attached to the filament in several ways: if the filament runs directly without interruption into the base of the connective, like the stalk of an ordinary leaf, it is said to be *innate* or *basifixed*; if the filament runs up the back of the anther as it were, so that the latter is more or less free at the base, the anther is *adnate* or *dorsifixed*; if the filament is attached by a slender apex to about the middle of the back of the anther, the latter is *versatile*. In some cases the anther is *pendulous* from the apex; it is then sometimes called *apicifixed*. In the Tulip, the capillary point of the filament runs up into a conical pit in the base of the connective.

Modifications.—The modifications of the anther result from various causes—from development of the connective, from the presence of appendages, from variation of form of the anther-lobes, and from special conditions of the internal cells; and there are also important differences in the manner of bursting, or *dehiscence*, for the discharge of the pollen.

The Connective.—The connective is normally a solid rib, running up the middle of the anther. If the lobes of the anther extend upward or downward beyond it, the summit or base of the anther (or both) becomes *emarginate*. On the other hand, the summit of the connective is prolonged in a membranous form in *Viola*, and also in the Compositæ. In *Paris* (fig. 226) the apex is lengthened into a point, also in *Asarum*, *Magnolia*, &c.; in *Xylopia* into a fleshy mass; in the Oleanders into a feathered process, &c. In two of the stamens of *Viola* the base of the connective has petaloid spur-like appendages; and still more remarkable states occur in the Melastomaceæ.

At other times the connective expands transversely, so that the lobes become more or less separated; in such cases it may be *ovate*, *orbicular*, &c. (*Melissa*, the Lime-tree, &c.). This is especially the case with the lower part; and examples may be found illustrating this point, forming a series from the state where the bases of the lobes are but slightly separated, to that in which they are inclined together at the summit at an angle of 45° (*Vitex*); or, further, the bases are carried out and up till they are horizontal, as in *Stachys*, *Prunella*, &c.; while in other instances this goes so far that the connective grows out into two distinct arms from the summit of the filament, bearing the solitary anther-cells at the tips: in *Salvia* (fig 227) one of the lobes is abortive, and represented by a petaloid plate.

Fig. 228.

Fig. 227.

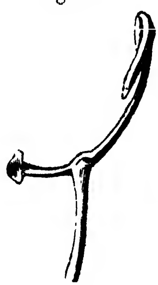


Fig. 229.

Fig. 227. Stamen of *Salvia officinalis*, with a half-anther containing pollen and the other half barren, separated by the bifurcation of the connective from the summit of the filament.
Fig. 228. Group of stamens with sinuate anthers, of the male flower of a Gourd.
Fig. 229. Stamen of *Vaccinium uliginosum*, with spur-like appendage and porous anthers.

Anther-lobes.—The lobes of the anther are commonly oblong; in the Grasses they are *linear*; but they vary with the form of the connective, and are sometimes *lunate* or *reniform*. In the Cucurbitaceæ they are remarkably convoluted (*sinuate*) into a flat scroll-like form (fig. 228). Not unfrequently they are attenuated upwards into free points, as in *Vaccinium* (fig. 229); in the Melastomaceæ the two lobes become confluent into a tubular process at the summit; while appendages are occasionally met with at the base of the lobes, as in *Erica* (fig. 230), &c.

Anther-loculi.—The lobes of most anthers exhibit internally four *cells* (*thecæ* or *loculi*) in the early stages of development, each lobe being divided into two by the *septum* extending from the connective to the suture (fig. 231). The septum (the *placentoid* of Chatin) is more or less destroyed during the maturation of the pollen in

most cases, leaving the anther *two-celled*, or *bilocular* (fig. 232). In some cases the internal substance of the connective is likewise absorbed, producing a true *unilocular* anther, as in *Alchemilla* and in Malvaceæ. In other cases the four cells are retained perfect,

Fig. 230.

Fig. 231.

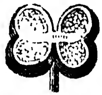


Fig. 232.

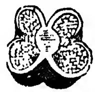


Fig. 233.

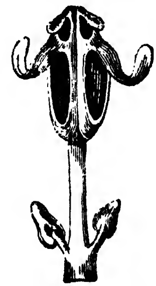


Fig. 230. Stamen of *Eri*[illegible]
Fig. 231. Section of an anther, its two lobes still divided into two cells by the *septa* reaching from the con[illegible]ctive to the *sutures*.
Fig. 232. Section of a bil[illegible]lar anther (the septa have been absorbed).
Fig. 233. Stamen of *Laur*[illegible]g a 4-celled anther with opercular dehiscence, and two lobes at the base of the filament representing divisions of a compound stamen.

as in the *quadrilocular* anthers of *Butomus*, where they are parallel, and of some Lauraceæ, where they become *oblique* so that the summits are all turned towards the face. The *dimidiate* unilocular anthers of *Gomphrena* and *Salvia* are so called from being only halves of anthers in which one lobe is abortive or suppressed. Anomalous one-celled anthers occur in *Polygala*. The unilocular lateral anthers of the diadelphous stamens of Fumariaceæ are *dimidiate*.

Dehiscence.—When the anthers are mature, the cells or loculi open and discharge the pollen. This dehiscence takes place in different ways: it may be *sutural*, *porous*, or *opercular*. *Sutural* dehiscence is the opening of the walls by splitting down vertically at the sutures, which may be *extrorse*, *introrse*, or *lateral* (see p. 126). A transverse slit is formed in the unilocular anther of *Alchemilla*, in *Lavandula*, and in *Lemna*. *Porous* dehiscence is where definite orifices are formed at some point of the wall of the loculus, as at or near the summit in *Solanum*, Ericaceæ (figs. 229, 230), &c. *Opercular* dehiscence results from the partial separation of a portion of the wall of the loculus, in the form of a kind of lid, as in the Berberry, where the front of each cell splits off at the sides and base, and turns back as if hinged at the top.

In the Lauraceæ (fig. 233) we find either two or four little lids of this kind, opening the two or four cells of the anthers.

If the anther be considered the equivalent of a leaf with infolded margins, then the groove between the two lobes would represent the margins of the leaf; but there is reason to suppose that no such infolding really occurs, but that two pollen-sacs are formed on either side of the connective without any involution of the margin.

Stamens of Gymnosperms.—The stamens of the Gymnospermia present remarkable conditions, which require separate notice.

Among the Coniferæ (see that order) the stamens of *Pinus* constitute the entire male flowers, and are conjoined into male cones, each anther forming a scale of the cone; they are bract-like plates, bearing on the lower face two parallel anther-lobes (bursting longitudinally or irregularly), beyond which the connective extends more or less as a scale-like process. In *Cupressus* the form of the anther is excentrically *peltate,* the lobes, three or four in number, standing under the overhanging connective; and it is similar in *Juniperus* and *Thuja.* In *Taxus* the *peltate* connective is more symmetrical, and radiately grooved above, having from three to eight vertical anther-lobes beneath: some authors regard this as a group of monadelphous stamens.

In the Cycadaceæ (for illustration see that order), where the anthers are scattered in large numbers over the lower face of the scales of the male cones, they occur mostly in the form of groups of four simple anther-lobes, with longitudinal dehiscence and arranged in the form of a cross. These are mostly described as parcels of unilocular anthers.

Number of the Stamens.—The stamens, taken collectively, present a number of characters, which have received technical names. The number of stamens in a flower is indicated by the terms *mon-androus, di-androus,* &c.; when more than twelve exist, the term *poly-androus* is employed. Upon the number of the stamens the Linnean classification was partly founded. When the number of the stamens is equal to, or some multiple of, the number of petals in the corolla &c., the flower is *isostemonous*; when the number is different (as in Scrophulariaceæ &c.) the flower is *anisostemonous.* When there is one whorl of stamens in the normal position, the term *haplostemonous* is employed; *diplostemonous* is used where there are two whorls, and *obdiplostemonous* where there are two rows of stamens, the outer superposed to the petals.

Relative length.—Two cases of inequality of length of the filaments are distinctly named, viz. the *didynamous* condition (figs. 234 & 235), when there are two pairs of stamens, one pair longer than the other, characteristic of many irregular Monopetalous flowers (Labiatæ, Scrophulariaceæ, &c.); and *tetradynamous*

(fig. 236), when there are four long stamens and two short ones, characteristic of the Cruciferæ. When the stamens are of unequal length in the same flower, or in different flowers of the same species (*e. g.* Primrose), the condition is called *dimorphic*, and has reference to the mode of fertilization to be hereafter mentioned.

The term *included* is employed to denote that the stamens do not reach beyond the corolla; *exserted*, that they are protruded from it; while *declinate* means that the exserted stamens are all curved over to one side.

Cohesion, etc.—The stamens are subject to apparent confluence or cohesion, like the other organs. If the filaments are only

Fig. 234.

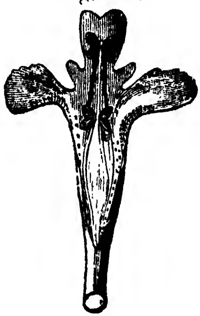


Fig. 236.

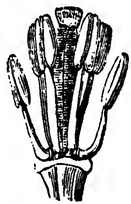


Fig. 235.

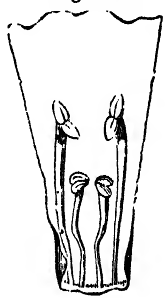


Fig. 234. Corolla of *Glechoma*, laid open to show the didynamous stamens.
Fig. 235. Corolla of *Digitalis*, laid open to show the didynamous stamens.
Fig. 236. Tetradynamous stamens of the Wallflower surrounding the pistil, the floral envelopes being removed.

partially separated so that they form a tube surrounding the

Fig. 237.

Fig. 238.

Fig. 239.

Fig. 240.

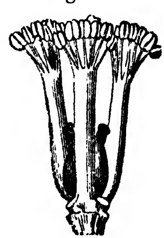


Fig. 237. Monadelphous stamens of *Malva*.
Fig. 238. Diadelphous stamens of Leguminosæ.
Fig. 239. Ground-plan of a Papilionaceous flower with diadelphous stamens 9+1 (the little circles round the solitary carpel).
Fig. 240. Triadelphous or polyadelphous stamens of *Hypericum ægyptiacum*.

style (or a column in a staminate flower of a diclinous plant) (fig. 228), the stamens are *monadelphous* (fig. 237), as in Malvaceæ, *Camellia*, &c. In Fumariaceæ they are coherent into two equal parcels, while in many Leguminosæ, of ten stamens, nine are united together and one free: these states are called *diadelphous* (figs. 238 & 239). In Hypericaceæ we have *triadelphous* (fig. 240) and *pentadelphous* states; but these, as also the state in Aurantiaceæ and various Myrtaceæ, are generally denominated *polyadelphous*, and are instances of branched stamens (p. 120).

Syngenesious signifies that the filaments are free, but the anthers coherent (fig. 241), as in Compositæ and Lobeliaceæ. *Gynandrous* indicates confluence of stamens and pistils, such as occur in Orchidaceæ, Asclepiadaceæ, *Aristolochia*, &c. (fig. 242). These terms, together with those descriptive of *adhesion* (*perigynous*, *epigynous*, &c.), have already been explained, as also the meaning of the words *monœcious*, *diœcious*, &c.

Fig. 241.

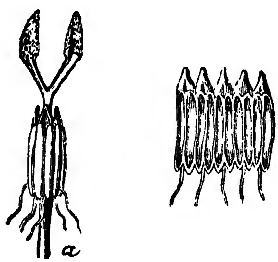


Fig. 242.

Fig. 243.

Fig. 241. Syngenesious stamens of Compositæ: *a*, the anthers surrounding the style as a sheath; *b*, the anthers removed and spread out, showing the free filaments.
Fig. 242. Section of the lower part of the perianth of *Aristolochia*, springing from the top of the inferior ovary. In the cavity of the perianth is seen the style, with the adherent anthers upon its sides.
Fig. 243. Clavate pollen-mass of *Orchis*, prolonged below into a *caudicle*, by which it attaches itself to the *rostellum* of the stigma.

Direction of Anthers.—Usually what is called the *face* of the anther is turned inwards towards the ovary, and it is then said to be *introrse*: but sometimes the reverse state exists, and the face is turned towards the floral envelopes, as in *Ranunculus*, *Colchicum*, &c., when the anthers are termed *extrorse*. Frequently the direction changes during the expansion of the flower, as in versatile anthers. (See also under Dehiscence, p. 123.)

Pollen.—The *pollen*, discharged from the anthers, consists in almost all cases of a fine powder composed of microscopic grains or cells corresponding to the *microspores* of the higher Cryptogams;

the form and appearance of the grains vary much, and will be spoken of hereafter. The pollen of the Asclepiadaceæ and Orchidaceæ, however, has a great peculiarity, in remaining permanently coherent into masses, often of a waxy character. In Orchidaceæ the *pollen-masses* or *pollinia* are either single in each loculus of the anther (as they are in Asclepiadaceæ), and then often furnished, as in *Orchis* &c., with a stalk-like process, called the *caudicle* (fig. 243), terminating in a gland-like base (*retinaculum*), by which they readily adhere to the stigma or to foreign bodies, such as insects; or the *pollinia* are two or four in each loculus, and devoid of a caudicle; sometimes the *pollinia* are numerous, and form merely a loose granular mass.

The external characters of the pollen-grains, their structure, and subsequent history will be treated of in the Third Part of this work, as they belong to the microscopic anatomy and the Physiology of Plants. The form of the pollen-grains is generally constant in the same plant; but great variations are often found within the limits of Natural Orders and sometimes in the same genus, so that, excepting the Orchidaceæ and Asclepiadaceæ, and a few other groups, they are not to be relied on as affording any very useful characters in Systematic Botany. Their size, form, and numbers are apparently in relation to their mode of dispersion by the wind or by insects.

The Gynæcium or Pistil.

Carpels.—The central essential organs of flowers, composing the *pistil*, consist, like the outer parts, of *phyllomes* or modified leaves; these constituent leaves are called *carpels*. The peculiar character of a carpel is, that it produces *ovules*, the rudiments of the seeds—usually upon the margins, but occasionally on other parts of the internal surface. In the Gymnospermia these ovules are developed upon the edges or surface of expanded carpels. In the Angiospermia, comprehending the great majority of Flowering plants, the carpels are folded up, either singly (fig. 244) or collectively, with the margins turned in so as to place the ovules in the interior of a hollow case. The case thus formed, enclosing the

Fig. 244. Fig. 245.

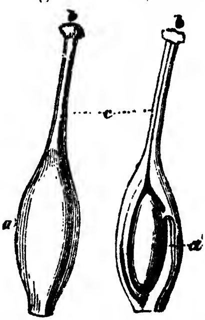


Fig. 246.

Fig. 244. Simple pistil of *Prunus*, consisting of a single carpel: *a*, the *ovary*; *c*, the *style*; *b*, the *stigma*.
Fig. 245. The same, opened, to show the *ovule* within the ovary.
Fig. 246. Cross section of the carpel of *Prunus*, showing that the ovule arises from the placenta at the confluent

ovules, is called the *ovary* (figs. 244 & 245, *a*, *a'*); the upper part of the carpel is frequently attenuated into a slender column called the *style* (*c*), at the extremity of which is a terminal glandular orifice or *stigma* (*b*, *b*), the borders of which are often more or less thickened or developed into processes of various kinds. Sometimes the *stylar* prolongation does not exist; and then the *stigma* is *sessile* upon the *ovary*.

The pistils are undoubtedly formed of carpels (carpellary leaves) in most instances. In some cases they appear to be formed by an expansion of the receptacle or axis of the flower, as in *Typha* and *Naias*; while their structure and venation are in some cases neither those of a leaf nor of an axis, but, as it were, intermediate between the two.

Phyllody.—The foundations of the doctrine that the carpels are metamorphosed leaves rest upon a very wide basis. The following observations include examples of some of the most important classes of proofs:—1. The carpel ordinarily possesses more of the character of a true leaf, as regards texture and colour, than the stamens or petals —approaching to the sepals, which we have seen to pass insensibly through the bracts into ordinary leaves. The resemblance is sometimes heightened during the development of the fruit, as we see in the legumes of some species of *Cassia*, and still more in the bladder-like pod of *Colutea*. 2. Abundant examples exist of the substitution of petals for stamens and pistils in abnormal flowers; and an almost equally common monstrosity consists in the substitution of isolated stunted green leaves for the carpels. In the Double Cherry, cultivated in shrubberies for the sake of its blossom, the stamens are generally replaced by petals, while the centre of the flower is mostly occupied by a pair of green leaves. (The single, fertile Cherry frequently has two pistils developed instead of one.) In a common monstrosity of the White Clover, the pod is usually replaced by a more or less perfect green leaf; the same occurs in garden Roses, where tufts of green leaves replace the pistils; and, in fact, examples of this kind are very abundant. 3. The more or less stunted green leaves which represent the carpels in the above-mentioned monsters frequently exhibit on their margins structures varying in character from almost perfect rudiments of ovules to cellular papillæ and leafy lobules. This is observed in the monstrous Clover, and has been especially remarked also in monstrous flowers of cultivated (forced) Tulips, of various Cruciferæ, Ranunculaceæ, Scrophulariaceæ, &c. The abnormal conditions in these cases are analogous to the normal condition in Coniferæ and Cycadeæ, the Gymnosperms, where the ovules are always naked on open carpels. 4. The production of ovules on the margins of carpels is analogous to what is seen in the development of *adventitious buds* on vegetative leaves, as in *Bryophyllum*, &c. Such buds, however, occur sometimes on the upper surface of leaves; and we find some carpels, as in *Nymphæa*, *Butomus*, &c., with ovules developed more or less extensively over the internal face. 5. The disposition or arrangement of the vascular bundles is usually that of the leaf, not that of the branch. 6. The structure, development, and mode of growth generally are those of the leaf and not of the branch. Exceptions, however, occur to the last two statements.

Placenta, Sutures.—The region of the carpel whence the ovules arise is called the placenta; and when in Angiospermous flowers the placentas are clearly and distinctly marginal, they must of course be *double*, from the meeting of the two edges; the same is true of the *stigmatic surfaces.* The line of union of the margins of carpels constitutes the *ventral suture*: the line corresponding to the midrib of the carpellary leaf is the *dorsal suture.*

An excellent example of a simple typical pistil formed of a single carpel is afforded by the legume of the Leguminosæ; as, for instance, in the Sweet-pea, where we find the ovary, with a ventral and dorsal suture, narrowed above into a short slender style, terminating in a slightly enlarged stigma. When we open the ovary, in the way it is broken in shelling peas for the table, we find the placentary margins separated at the ventral suture, each carrying away half the ovules, demonstrating clearly the double character of the placenta.

Modifications.—Pistils differ extremely in different plants, from dissimilarity in the number, degree, and mode of union of the carpels, as well as in the relative degree of development of the different regions of the carpels, and with these may be associated the peculiarities arising from adhesion of the outer circles.

Numerical relation.—The number of carpels is most frequently less than that of the organs in the outer whorls, being very frequently reduced to two, and often to one. On the other hand, multiplication of the number is met with in certain Orders, where the receptacle is generally more or less enlarged to make room for them.

A large portion of the Gamopetalous Dicotyledons, with a quinary arrangement of the calyx and corolla, and often of the stamens, have dicarpellary pistils, as Gentianaceæ, Apocynaceæ, Solanaceæ, &c. Leguminosæ with quinary flowers have a solitary carpel. The agreement of the number of carpels with the other organs is almost universal in the ternary flowers of Monocotyledons, as in Liliaceæ, Iridaceæ, Orchidaceæ, &c. Multiplication of carpels is especially frequent in the Ranunculaceæ, Magnoliaceæ, and some other Orders.

Apocarpous Pistil.—In the typical pistil above described, and which really exists in Leguminosæ (for instance), the organ, being composed of one carpel only, is *simple.* A carpel may be solitary in a flower, from suppression of the remainder of the circle; or there may be in the same flower several distinct, *i. e.* uncombined, carpels, as in Larkspur, Aconite, *Magnolia*, *Ranunculus*, *Fragaria*, &c.: in these cases the terms *multiple pistils* is occasionally used, or we may say carpels *distinct*, three, five, or numerous, as the case may be. The term *apocarpous pistil* includes both the solitary carpel and the multiple pistils. In the case of multiple pistils,

where the receptacle is flat the carpels are in *whorls*; but if the receptacle is elongated the carpels are arranged *spirally*, as in *Magnolia*.

Syncarpous Pistil.—Where, as very frequently happens, the carpels cohere together, as the stamens do in the condition called monadelphous, a *syncarpous* or *compound pistil* is formed; and as the carpels occupy the apex of the receptacle, they do not form an open organ, like the tube of filaments in *Malva* for example, but a closed case, appearing externally like a solid body, mostly with ridges and grooves on the outside, indicating its compound nature.

The union varies very much in degree; even in multiple pistils we find the carpels sometimes cohering strongly while young, and separated only as the seeds ripen; and in true compound pistils the union does not always extend to the summit of the ovarian region, as we observe in the Saxifragaceæ, where the apices of the ovaries diverge. More frequently the ovarian regions are firmly coherent; and then the *styles* may be wholly free—Pink, *Silene* (fig. 173), *Hypericum*, &c.; or united part of the way up, as in some Malvaceæ (fig. 247); or entirely, but with the stigmas distinct, as in *Geranium*, &c.; or the stigmas may also be confluent (Primulaceæ, Solanaceæ, &c.). Sometimes, however, the styles or stigmas exhibit the reverse condition, and are split into two parts, as in the styles of *Drosera*, *Euphorbia*, &c.

Adhesion.—The conditions arising from adhesion or want of separation have been referred to already, under the names of *superior* or *inferior calyx* or *ovary*. The condition depends on this circumstance—whether the vascular bundles for the carpellary whorl are detached at once from the axis, or whether they are held together by a sheath of cellular tissue for a time before becoming detached. They are always associated with cohesion when more than one carpel exists.

The styles, when the ovary is inferior, are either coherent, as in Iridaceæ (fig. 260), or distinct, as in the Umbelliferæ (fig. 172) and Rubiaceæ. In *Saxifraga* (fig. 171), and in some other cases, the ovary is half-inferior. When the stamens are consolidated with the pistil, the *gynandrous* condition is produced. In Orchidaceæ the filaments are inseparable from the style, forming a *column* surmounting the ovary; in Asclepiadaceæ the anthers adhere to the summit of the free compound style; in Aristolochiaceæ the filaments apparently adhere to the base of the compound style (fig. 242). (See under Aristolochiaceæ.)

Compound pistils are sometimes smooth and even on the outside, showing no sign of their compound nature, as in *Primula*, &c.; in other cases they exhibit more or less deep furrows at the lines of junction, sometimes dividing them into lobes. But the internal structure of the ovary generally indicates the number of carpels entering into its composition very plainly.

Multilocular Ovary—Placentation.—When the carpels are firmly and organically united by the surfaces of contact, we obtain the type of a *compound multilocular* or *many-celled ovary* (fig. 248)*.

Fig. 247.

Fig. 248.

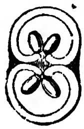


Fig. 249.

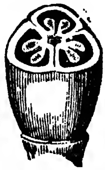


Fig. 250.

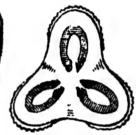
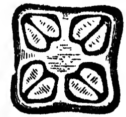


Fig. 251.



Multilocular compound ovaries.

Fig. 247. Ovary, styles, and stigmas of *Malva*.
Fig. 248. 2-celled ovary of Scrophulariaceæ.
Fig. 249. 3-celled ovary of *Lilium*.
Fig. 250. 3-celled ovary of *Commelyna*.
Fig. 251. 4-celled ovary of *Fuchsia*.

In these cases the sides of the constituent carpels are folded inwards, so as to meet in the centre, and thus form partitions between the chambers or *loculi*. The placental margins of the infolded carpels are retroflexed, constituting *central* or *axile* placentas. The partitions are called *dissepiments*, and are necessarily double, being composed of the conjoined side-walls of contiguous carpels. In such ovaries the *dorsal* sutures are in the outer wall, while the ventral sutures meet in the centre (fig. 248).

Examples of this kind of ovary are furnished by Liliaceæ (fig. 249) and many other Monocotyledonous orders, by Ericaceæ, Solanaceæ, Scrophulariaceæ, &c. In some cases the ventral sutures and placentas are not directly confluent, but adhere to a central prolongation of the receptacle running up between them, as in Geraniaceæ (fig. 276), &c.

False or *spurious dissepiments* occur occasionally both in compound and simple ovaries, consisting of membranes or plates developed from the placenta or from the dorsal suture, and subdividing the originally single cavity formed by individual carpels. Thus in *Linum* the 5-carpellary ovary would have five loculi, were it not that a spurious dissepiment extends inwards from the dorsal suture to the placenta in each loculus, and divides the ovary into ten loculi. In *Astragalus* (fig. 252) the simple ovary is divided by the inflexion of the dorsal suture, and in *Datura Stramonium* a false septum is formed in each of the loculi of the ovary. The *transverse* false septa found in various Leguminous ovaries, such as *Cathartocarpus* &c., are likewise outgrowths from the walls of the carpel.

Unilocular compound Ovary.—If the carpels are not inflexed, but cohere by their contiguous margins, they form a hollow case

* The term *cell*, though commonly used, is objectionable, as leading to confusion with the cells which make up the tissues of the plant. On this account the word *loculus* is preferable.

with only a single cavity; and as the lines of junction of the carpels are on the outer wall, the placentas must stand inside those lines; in this way is formed a *unilocular compound ovary* with *parietal placentas* (figs. 253–255). There are no dissepiments; and the ventral sutures, alternating on the outer walls with the dorsal sutures, are, in such cases, like the placentas within, formed of the confluent margins of two different carpels instead of those of the same carpel.

We find almost every possible degree of transition between the *parietal* and the *axile placentas*, according as the placentiferous margins project more or less into the interior of the ovary. True parietal placentas are found in Violaceæ (fig. 254), Gentianaceæ (fig. 253), Cistaceæ (fig. 255), &c. In *Papaver* we have the margins turned-in so as nearly to reach the

Fig. 252.

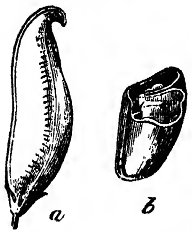
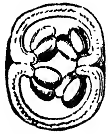
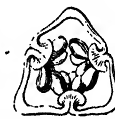
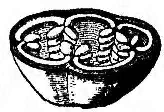


Fig. 253. Fig. 254. Fig. 255.







Unilocular compound ovaries.

Fig. 252. *a*, legume of *Astragalus*; *b*, cross section, showing a false dissepiment formed by the inflexion of the suture.

Fig. 253. Ovary of Gentianaceæ.
Fig 254. Ovary of *Viola*.
Fig. 255. Ovary of *Cistus*.

centre (as imperfect dissepiments); in some Hypericaceæ (*H. graveolens*) the originally axile placentas become parietal by separation during the ripening of the fruit, while in Cucurbitaceæ the originally distinctly parietal, although greatly inflexed, margins ultimately cohere so as to form an axile placenta.

In Cruciferæ we have an anomalous condition, where there are two double parietal placentas, but from the central line of each projects a plate passing across the cavity and forming a kind of spurious septum, called a *replum*; so that each cell contains only the two half-placentas formed by its own margins.

Free central Placentas.—In some Orders, where the walls are as in the unilocular compound ovaries above described, the placentas are found as a free column or expanded mass in the centre of the common cavity. This forms the *compound unilocular ovary with a free central placenta*. In Primulaceæ, Santalaceæ, and some other Orders, where this kind of placentation occurs, the placentas are free from their very earliest state, and are seen to be direct prolongations of the receptacle or axis within the carpels.

The appearance of a free central placenta is presented in Caryophyllaceæ by the obliteration of the partitions which pass between the outer walls and the centre of the carpels.

By Baillon a peculiar process from the placentas over the ovules is called the *obturator*; it is very conspicuous in Euphorbiaceæ.

Various modes of Placentation.—The placentas have been spoken of as *double*, on account of their origin: where only one ovule exists in a cell, it is assumed that one at least is suppressed; but this other is not unfrequently developed in the Cherry, Almond, &c. (causing the double kernels). In Leguminosæ the double placental base is so narrow that the ovules are placed one over another, and form what appears like a single line. In Larkspur, Columbine, &c. there is a distinct double row; in many cases each placenta has a double row of ovules; while axile placentas are frequently thickened and enlarged, so as to bear a large collection of ovules, closely packed. In *Papaver* the ovules exist all over the imperfect septa; in *Nymphœa* all over the sides of the dissepiments, and *not at the margins*; in *Butomus* all over the inside of the carpels, &c. Where ovules arise from the base of a carpel, either singly or in larger numbers, the placentation is called *basilar*; it is in most cases a slight modification of free central.

The Style.—The styles require no particular notice beyond the statements already made, except in regard to their irregular position in some cases. The style is really produced from the apex of the carpel; but in various Rosaceæ the ovarian part of the structure grows faster and so disproportionately that it leaves the style on one side (*lateral*) (*Fragaria*, fig. 256), and sometimes even grows out and up so much that the style, then called *basilar*, seems to arise from the base (*Alchemilla*). In the Boraginaceæ and Labiatæ (fig. 205) a similar condition of the styles exists in a compound pistil; the styles in these plants are confluent, and arise as a solitary column from a deep depression in the centre of the 4-lobed ovary, communicating with the cells near the base as in the Rosaceæ referred to. These styles of Labiatæ are called *gynobasic*. A *dimorphic* condition of the pistil especially affecting the length of the style is met with in some flowers, *e. g.* Primroses, some of which have short, others long styles, as explained under Fertilization.

The Stigma.—The stigma is either situated at the end of the style or, where this structure is wanting, it is *sessile* on the ovary. Instances of *sessile* stigmas are furnished by the compound pistils of *Papaver* (fig. 262), Nymphæaceæ, &c., where the stigmas form radiating ridges on the top of the flattened ovaries. The elongated stigmatic surfaces on the inner sides of the beak-like points of the simple pistils of *Ranunculus* and allied plants are almost to be

called sessile stigmas; and these form a transition to the long stigmatic ridges which extend down the inner sides of the styles

Fig. 256.

Fig. 257.

Fig. 258.

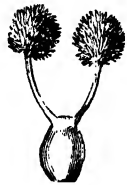


Fig. 259.

Fig. 256. Lateral style of *Fragaria*.
Fig. 257. Pistil of a Grass, with feathery stigmas.
Fig. 258. Pistil of a Grass, with penicillate stigmas.
Fig. 259. Stigmas of *Crocus*.

of most Caryophyllaceæ. When it is properly terminal it exhibits a great variety of conditions, both as regards composition and structure. Its form is sometimes associated with the method of fertilization by insects or otherwise, as afterwards explained.

Fig. 260.

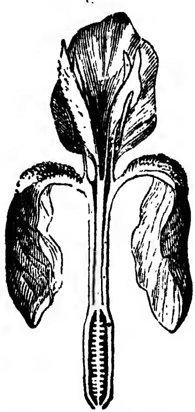


Fig. 262.

Fig. 261.

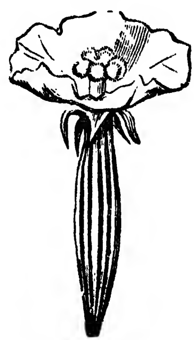


Fig. 260. Vertical section of flower of *Iris*, the style terminating in erect petaloid stigmatic lobes.
Fig. 261. Female flower of *Cucumis sativus*, with a short style and lobed stigma.
Fig. 262. Ovary of *Papaver*, with radiate sessile stigmas.

It has been stated that the styles of compound ovaries are often *distinct*; the stigmas are also often distinct on compound styles, indicating the

number of constituent carpels. Moreover these distinct stigmas are occasionally split down into two arms (*stigmata bicruria*), corresponding to the two placentas below: the one-celled ovary of Grasses and Compositæ (fig. 264) bears a two-armed stigma; and the stigmas of the compound ovaries of *Euphorbia* and some *Droseræ* are double the number of the carpels. Sometimes the distinct arms of different carpels cohere, and form stigmas equal in number to the placentas, but alternating with them.

Form and Position.—Stigmas, simple or compound, when distinct, are either *terminal* or *lateral*: in the latter case the stigmatic surface is on the ventral side. Their form is generally slender and thread-like, with a glandular stigmatic surface; but in the Grasses the stigmas are feathery (fig. 257) or *penicillate* (fig. 258); in the

Fig. 263.

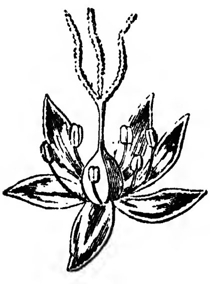


Fig. 264.

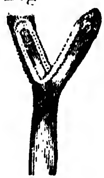


Fig. 265.

Fig. 266.

Fig. 267.

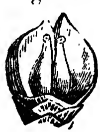


Fig. 263. Flower of *Luzula*, with one style and filiform stigmas.
Fig. 264. Linear stigmas of Composite plant, with papillose surfaces.
Fig. 265. Ovary of *Colutea*, with style and *lateral* stigma.
Fig. 266. Open carpel of *Pinus*, with two naked ovules at the base.
Fig. 267. Young female blossom of *Juniperus*, with the front carpel removed, showing the naked ovules.

Iridaceæ they are petaloid (fig. 259) or very much enlarged, as in *Iris* (fig. 260); and in other cases they are *capitate* (fig. 256), *lobed* (fig. 261), *peltate*, *radiate* (fig. 262), *filiform* (fig. 263), *linear* (fig. 264), &c. In Leguminosæ the stigmatic surface of the simple style is *lateral* (fig. 265).

The orifice of stigmas leading to the canal of the style is more or less filled by the glandular and capillary processes which clothe their surfaces; and, indeed, to the naked eye, the canal of the style does not appear permeable.

Gymnospermous Pistils.—The pistil of Gymnospermous plants consists of scales or *open carpels*, collected into *cones*, bearing exposed

ovules, so that no representative of the stylar or stigmatic regions exists here. Among the Coniferæ, *Pinus* and its allies have scale-like carpels with a pair of ovules on the upper surface, at the base (fig. 266); the structure is analogous, although the form of the scale differs, in *Thuja*; the Cypress has peltate scales, with numerous ovules; in *Juniperus* each of the three scales has only one (fig. 267). In *Taxus* the ovule is a solitary structure, a kind of free ovule, growing out from the apex of a small cone formed of barren scales. In the Cycadaceæ, *Cycas* has large leaf-like carpels, with numerous marginal ovules; *Zamia* has peltate scales, more like *Cupressus*, with the ovules pendent from the thickened summit.

By some authors what is above described as a naked ovule is thought to be an ovary (see under Gymnosperms).

Sect. 10. Products of the Essential Organs of Flowers.

Ovules.—Ovules are the rudiments of seeds, and arise from the placentas situated in the ovaries of Angiospermous plants (figs. 253–255), and on the margins or surface of the open carpels of Gymnospermia (figs. 266, 267). They originate as cellular papillæ at an early stage of development of the ovary, and acquire a definite form and structure by the time the flower expands.

Ovules are by some observers regarded, in part at least, as a kind of bud; for not only do they appear in the positions occupied by adventitious buds on vegetative leaves, as in *Bryophyllum*, but abnormal leaf-like carpels often bear bulb-like structures and foliaceous lobes, in place of the ovules, on their free margins. By others they are considered, at least so far as their outer coat is concerned, to be modified leaves or portions of such leaf. In most cases they originate from the margins or surface of a carpellary leaf; but in some cases they originate from the axis (free central placentation), and are then either lateral or terminal, as in Piperaceæ, where the end of the axis becomes the nucleus of the ovule. Other illustrations are afforded by *Taxus* and *Polygonum*.

Number.—The number of ovules in the ovary, or in one cell of a compound ovary, varies between wide limits. Thus the ovule is *solitary* in the simple ovaries of *Ranunculus*, *Prunus* (fig. 245), &c., in the compound ovaries of Polygonaceæ &c., and in each cell of the bilocular ovaries of the Umbelliferæ &c.; the number is still small and *definite* in the simple pistils of many Leguminosæ, in the cells of the compound ovary of *Quercus*, &c.; in a very large proportion of compound ovaries, whether unilocular or multilocular, the ovules are very numerous on each placental surface, and they are termed *indefinite*, as in *Primula*, *Papaver*, &c. &c.

Funiculus.—A fully developed ovule is usually attached to the placenta by a short stalk, called the *funiculus*, *podosperm*, or *umbilical cord*; where this stalk does not exist, the ovule is *sessile*; in a few cases the funiculus is very much elongated (Plumbaginaceæ).

Relative Position.—Special terms are used to indicate the position occupied by ovules in the ovary, and more particularly their direction. If the placenta is at the base of the ovary, and the ovule, springing from that situation, points upward, as in Polygonaceæ and Compositæ, the ovule is called *erect*; if it is attached at the summit, and hangs straight down, as in the Birch, Dipsaceæ, &c., it is *suspended*; when the placenta is central or parietal, the ovule may turn upwards and be *ascending*, may point straight outwards or inwards and be *horizontal*, or may turn downwards and be *pendulous*. In Plumbaginaceæ the ovule is suspended from the end of a long funiculus, which arises from the base of the ovary as in the erect condition.

Where numerous ovules exist on a central placenta, it is very common to find the upper ones ascending, the middle horizontal, and the lower pendulous, so that the direction becomes indefinite.

Parts of an Ovule.—The ovule arises from the placenta as a conical papilla, which soon becomes elongated into an oval body, the *nucleus*, raised on the stalk or *funiculus*. By the time the flower opens, the *nucleus* (figs. 268–270, *a*) generally becomes covered up by the *coats* or envelopes, which originate as circular ridges from the point where the funiculus is attached, and gradually grow up over the nucleus. The coats do not completely close in the ovule, but leave an opening at its summit, called the *micropyle* or *foramen* (figs. 268–270, *b*). The base of the nucleus, where the coats arise, is called the *chalaza*; the internal coat (the *secundine* of Mirbel) is the first formed; it is denominated the *integumentum internum*, or the *tegmen*; where only one coat exists, it is called the *integumentum simplex*. The outer coat, which grows up after the inner (the *primine* of Mirbel), is called the *integumentum externum*, or sometimes the *testa*. Sometimes, as in *Welwitschia*, the primine is prolonged beyond the apex of the ovule in the form of a tube greatly resembling a style (see under Gnetaceæ). The orifice named the *micropyle* forms a canal passing through both coats down to the point of the nucleus; and the portions passing through the outer and inner integuments are often called, respectively, the *exostome* and *endostome*. The point where the seed afterwards breaks away from the funiculus is marked by a scar, which is called the *hilum*.

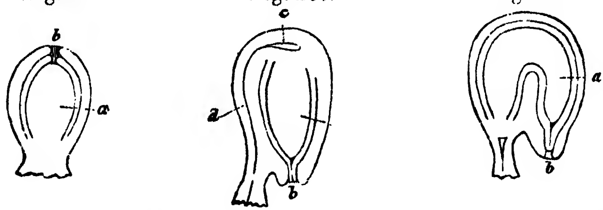
In the Mistletoe the nucleus is naked, no coats being formed; in many cases there is only one coat; most ovules of Monocotyledons have two.

The coats of the ovule are usually regarded as foliar in their nature, the nucleus as axial—by others as a "trichome" or superficial emergence from the foliar coat of the ovule. The nucleus may be regarded as the equivalent of a macrosporangium among higher Cryptogams.

The above is a description of the ovule of what may be called the normal form, such as we find in *Polygonum*, &c.: where the nucleus is straight and the *micropyle* is at the end opposite the attachment of the *funiculus*, and the *chalaza* next the *placenta*, such an ovule is called *straight*, or, more technically, *atropous* or *orthotropous* (fig. 268).

Inversion and Curvation of the Ovules.—Very frequently the *funiculus* grows in a state of confluence with the outer integument, during the development of the ovule, so as to push up the base of the nucleus until it is completely inverted (fig. 269), and

Fig. 268. Fig. 269. Fig. 270.



Diagrammatic vertical sections of ovules: *a*, the nucleus; *b*, the micropyle; *c*, chalaza; *d*, raphe.

Fig. 268. An atropous or orthotropous ovule.
Fig. 269. An anatropous ovule. Fig. 270. A campylotropous ovule.

the micropyle (*b*) points to the placenta, while the chalaza (*c*) is at the opposite end, the nucleus being straight as in orthotropous ovules: this is the *inverted* or *anatropous* condition (Compositæ, Liliaceæ, &c.); and as the funiculus is confluent with the outer coat, the *hilum* (the external point of junction of the *funiculus* with the body of the ovule) is left in its original position, and therefore close beside the inverted micropyle. The adherent portion of the funiculus often forms a kind of ridge extending from the hilum to the chalaza: this is termed the *raphe* (fig. 269, *d*). Other ovules become anatropous not by reflexion, but by unequal growth.

The inverted ovule is a straight ovule with a long funiculus confluent with the outer coat: in *Fumana* (Cistaceæ) the real condition often actually illustrates this; and in seeds formed from anatropous ovules the raphe sometimes separates (*Zygophyllum*, *Willdenovia*).

The position of the raphe with reference to the ovule varies in different cases; sometimes it is *ventral*, or on the side of the ovule nearest to the placenta, sometimes *dorsal*, at other times *lateral*.

A curved or *campylotropous* ovule (fig. 270) is formed by the

bending over of the nucleus upon itself in the form of the letter U, carrying the *micropyle* (*b*) over, but leaving the *chalaza* in its natural vicinity to the hilum. There is no raphe in such ovules.

Another condition more rarely met with is the horizontal or *amphitropous* ovule, intermediate between straight and inverted, the adherent funiculus pushing up the chalaza at one end, while the micropyle descends in a corresponding degree, until the axis of the ovule becomes horizontal, and parallel with instead of at right angles to the placenta.

In the first instance all ovules are straight, but they mostly become curved during the course of their development.

The Embryo-sac.—At the time when the flower expands, there exists a more or less considerable sac or cavity excavated in the substance of the nucleus, the upper end of which sac is situated just within the apex. This cavity is called the *embryo-sac*, being really a sac or bag with a proper wall, within which the *embryo* or rudiment of the future plant is developed after fecundation. It is analogous to the *macrospore* of Cryptogamous plants.

The phenomena of fecundation and of the early development of the embryo, together with the minutiæ of the anatomy of ovules, are reserved for the Physiological part of this work.

The further morphological peculiarities of the ovular structures will fall best under the head of the *seed* or completed product, previously to examining which we must follow out the ultimate history of the pistils and associated organs forming the *fruit*, in which the ripe seeds are found.

The Fruit.—The fertilization of the ovules usually takes place soon after the opening of the flowers, or sometimes even before their expansion. During the subsequent changes by which the ovules are converted into seeds, the ovary (and occasionally other parts of the flower) undergoes further development, and becomes what is technically called the *fruit* or seed-vessel.

Changes during the ripening of the Fruit.—Generally the stamens and corolla, and not unfrequently the calyx also, fall away or wither up after fertilization, and the styles, with the stigmas, mostly disappear; but the style sometimes persists, and even undergoes enlargement, forming a kind of *beak* or *tail* to the fruit, especially in simple fruits formed of one carpel (*Ranunculus, Clematis, Geum*, fig. 289, &c.). The calyx, when *inferior*, remains in many cases as a loose cup or envelope surrounding the fruit (as in Labiatæ, many Solanaceæ, fig. 184, &c.); or, when *superior*, its segments, enlarged or withered, form a kind of crown to the fruit (Compositæ, Campanulaceæ, &c., fig. 283), and the tubes of adherent calyces always enter into the composition of the inferior fruits (figs. 298–303). In some cases the calyx and the corolla, in other cases the receptacle,

become blended with the ovary or ovaries to form the fruit; and a still more complex kind of fruit is formed by all the flowers of an inflorescence becoming conjoined into a common structure during the ripening of the seed, so as to form a collective fruit, such as occurs in the Pineapple (fig. 308), Mulberry (fig. 307), Bread-fruit, the Fig (fig. 306), cones of Firs, &c.

Considered as developments of the carpels alone, many fruits in their mature condition depart widely in appearance from the ovaries from which they are produced, the morphology of fruits exhibiting perhaps more remarkable cases of actual metamorphosis than any other parts of plants. Hence it is often difficult to judge from a fruit what kind of pistil the flower has possessed, and the structure of fruits can only be understood by a study of their progressive development from the immature to the mature condition.

The most important source of change is the *suppression* of chambers or loculi of the ovary, together with the abortion of ovules. Thus the flower of the Birch has a two-celled ovary with one ovule in each cell; but one cell with its ovule is constantly abortive and almost entirely disappears in

Fig. 271.

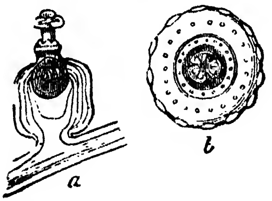


Fig. 272.

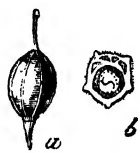


Fig. 271. Female flower of the Oak: *a*, vertical section; *b*, cross section.
Fig. 272. Fruit of the Lime (*Tilia*): *a*, entire; *b*, cross section.

the fruit. In the female flower of the Oak and hazel-nut there are three cells, each with two ovules (fig. 271); but only one cell is found in the ripe fruit, and this is filled by one solitary remaining seed, as we find in the Acorn or nut. In the Lime there are several cells in the ovary, but generally all but one are obliterated in the fruit (fig. 272); and similar cases are by no means uncommon. In these cases the dissepiments, called in the fruit *septa*, are not broken down, but pushed to one side and obliterated by the pressure exercised by the developed seed.

On the other hand *spurious partitions* are sometimes formed, as in *Datura Stramonium*, which has a four-celled fruit derived from a two-celled ovary: and in the pods of Leguminosæ cross partitions are often produced between the seeds.

The original conditions are frequently still further concealed by the alterations in the texture of the coverings of the fruit, next to be described.

The Pericarp.—The "wall" of the fruit is the substance formed from the carpels, or (when present) from the other component

structures. It constitutes the case enclosing the ripe seed or seeds, and is called the *pericarp.* The pericarp is of very different structure in different fruits. When the fruit is mature, it may be *dry, membranous, leathery (coriaceous), woody,* or *succulent*; or it may be succulent externally and woody within, or succulent internally and woody or leathery outside.

The ripe pods of common Peas afford examples of a dry membranous pericarp; the Flags (*Iris*) have a *leathery* pericarp; the common Hazel-nut &c. have a *woody* pericarp. The pericarps of the Grape and the Gooseberry are *succulent* or *baccate.* The Plum, Cherry, &c. are succulent externally and woody within (*drupaceous*); the Orange, the Pomegranate, the Pumpkin, &c. are succulent within and leathery or horny outside.

When the *pericarp* is uniformly membranous or woody, without distinction of layers, no subdivisional terms are applied to it. The same holds good in respect to the simple *succulent pericarp* of such fruits as the Grape and Gooseberry. When there is a distinction into layers, formed by a gradual alteration of the texture of the inner and outer parts during maturation, we distinguish between an *epicarp* and an *endocarp* or *pyrene*—as, for example, in the Plum, Cherry, Walnut, &c., where there is a succulent *epicarp,* and a woody *endocarp* forming the "stone;" the "core" of the Apple is a membranous endocarp. When a fruit, such as the Orange, Pomegranate, Litchi, &c., is firm externally, with a leathery or woody *epicarp* and a succulent *endocarp,* the latter is generally derived from development from the placental regions. In common "stone-fruits" the two regions are often distinguished by the names *sarcocarp* (or pulp) and *putamen* or *pyrene.* In the Date-Palm (fig. 280) the "stone" consists of the albuminous seed, which is invested by a succulent pericarp. In other Palms, such as *Areca,* the pericarp is fibrous. In hard-rinded succulent fruits we have an internal *sarcocarp* enclosed by a *cortex* or rind.

Many authors, following De Candolle, divide the pericarp into *epicarp, mesocarp,* and *endocarp.* It may be observed here that the distinction between endocarp and epicarp, in the common stone-fruits, arises entirely during the ripening of the fruit; the two regions are originally alike and undistinguishable; it is well known that the easy separation of the pulp from the stone is a sign of ripeness.

Dehiscence of Fruit.—Some fruits, more particularly the succulent kinds, but also many dry fruits, do not burst to discharge their seed or seeds when ripe; these are called *indehiscent fruits.* The pericarp rots away, or is broken irregularly or when the seed germinates. Most dry fruits, more those formed of more than one carpel, burst open or separate into pieces in a regular manner when mature, and are consequently *dehiscent.*

Dehiscence takes place generally (1) by the separation or splitting of the sutures of the carpels in a vertical direction, or (2) by the dissociation of coherent carpels, or (3) by both together. The parts which

separate in the first way are called *valves*; and this mode of bursting is termed *sutural* or *valvular dehiscence.* The separated carpels in the second mode are called *cocci* if they do not open as explained in a subsequent paragraph. Sometimes the valves only separate for a certain distance from the summit, forming teeth (fig. 273). In a few cases the dehiscence is *porous*; in others the upper end of the fruit falls off like a lid, by *transverse* or *circumscissile dehiscence* (fig. 274).

Fig. 273.

Fig. 274.

Fig. 275.

Fig. 273. Burst capsule of *Cerastium.*
Fig. 274. Capsule of *Anagallis* (sometimes called a pyxis), opening by circumscissile dehiscence.
Fig. 275. Burst fruit of *Illicium* (Star Anise).

Valvular Dehiscence.—When the dehiscence is *valvular* the fruit is named bi-, tri-, multivalvular according to the number of valves or pieces into which it splits. This mode of dehiscence is subject to several modifications, according as the splitting takes place through the dorsal or through the ventral suture, or through both at the same time. It is still further complicated by the circumstance that the placentas sometimes remain attached to the valves, while at other times they break away from the valves, as in the condition called *septifragal.*

A few examples may be here given of the various modes in which valvular dehiscence is effected; and the student will find the subject far more readily intelligible if he refer to some collection of seed-vessels where the fruits are correctly named. In the case of *simple* or of *apocarpous* fruits, there is no partition or dissepiment, the cavity being simple; in such cases valvular dehiscence takes place:—*a*, through the ventral suture, as in the Columbine (*Aquilegia*), the Star Anise (*Illicium*, fig. 275); or, β, through the dorsal suture, as in *Magnolia*; or, γ, through both sutures at the same time, as in the pod of the Pea and other Leguminous plants (fig. 286). In this latter case there are two valves, but only a single carpel.

In *unilocular syncarpous* fruits, where the compound carpels cohere by their edges which are not infolded, dehiscence takes place:—*a*, through the ventral sutures, when the placentas are found on the margins of the valves, as in Gentians (fig. 253), each valve in this case representing a carpel; β,

through the dorsal sutures, when the placentas will be found in the middle of the valves, as in the Violet (fig. 254). In such fruits each valve consists of two half-carpels combined. In the Orchidaceæ the capsules dehisce in the manner last described, with this further peculiarity—that the valves, bearing the placentas in the middle, separate from the midribs or dorsal sutures, leaving these latter attached together at the top, and thus forming an open framework supporting the remains of the perianth.

In *multilocular syncarpous* fruits, where the sides and margins of the component carpels are infolded, so as to form partitions or dissepiments, the dehiscence is likewise through the dorsal, or ventral, or through both sutures; thus dehiscence takes place:—*a*, *loculicidally*, through the dorsal sutures, so as to open the loculus or cavity of the carpel from behind; each valve in this case represents two half-carpels (figs. 277, 278); or, *β*, *septicidally*, through the septa, so as to isolate the previously combined carpels (fig. 276). Each segment in this case represents an entire carpel.

Fig. 276.

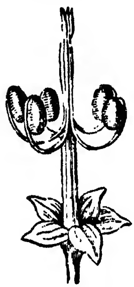


Fig. 277.

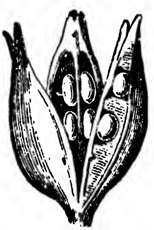


Fig. 278.

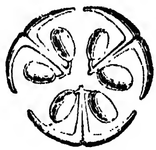


Fig. 276. Ripe fruit of *Geranium*, the tailed *cocci* separating elastically from the carpophore.
Fig. 277. Burst capsule of *Iris*, with loculicidal dehiscence.
Fig. 278. The same in cross section.

Septicidal and loculicidal dehiscence may occur in the same fruit, as in the Foxglove (*Digitalis*), the capsule of which first divides into its constituent carpels septicidally, and afterwards each carpel splits loculicidally into two valves; the four valves so produced represent each a half-carpel.

Both the loculicidal and septicidal modes of dehiscence are sometimes associated with what is termed *septifragal* dehiscence. This occurs when the *septa* or partitions bearing the placentas are broken across; the effect of this is that the valves break away from the placentas, leaving part or the whole of the latter standing in the centre of the fruit on a kind of column, as in *Andromeda*, *Convolvulus*, *Rhododendron*, &c. *Septifragal dehiscence* takes place by itself in the *siliques* or pods of Cruciferæ, where the valves separate from the parietal placentas, leaving them in the centre supporting the ovules (figs. 295 & 296).

Schizocarps.—In some instances, as in *Galium*, the carpels separate one from the other without opening. In such a case the term *schizocarp* is employed to designate the whole fruit, while its component carpels are

called *cocci*, or where there are two, as in Umbellifers, *mericarps* (fig. 300). More frequently the carpels not only separate septicidally but each one bursts, through the dorsal suture, as in *Geranium* (fig. 276), or through the ventral suture, as in *Colchicum*.

Dehiscence by teeth only differs from that by valves in the smaller degree of separation. The fruits or seed-vessels of Caryophyllaceæ dehisce by teeth. Sometimes the teeth are equal in number to the carpels, as when the dehiscence is through the ventral sutures only (*Lychnis*); sometimes double the number of the carpels, when the splitting takes place through both sutures (*Dianthus*) (fig. 273).

Porous Dehiscence arises from the formation of orifices in the walls of a dry capsule, allowing the seeds to escape. In the Poppy (*Papaver*) a circle of *pores* is formed round the upper edge of the fruit, just beneath the stigma; in *Antirrhinum* and *Linaria* there are two or three orifices near the summit of the capsule; in some Campanulas a pore is formed at the base of each cell.

In all these cases the orifices are formed from thin spots in the walls, which tear open, their edges curling back in more or less regular teeth: the dehiscence of *Antirrhinum* is connected by that of *Scrophularia*, *Digitalis*, &c. with the dehiscence into a crown of teeth as in *Primula* and Caryophyllaceæ.

Transverse or **Circumscissile Dehiscence**, observed in the membranous capsules of *Hyoscyamus* (fig. 294), *Anagallis* (fig. 274), *Plantago*, &c., and in the woody fruits of *Lecythis*, arises from a transverse fissure running round the wall and splitting off the upper part of the fruit like a lid. A dehiscence analogous to this occurs in the *lomenta* of various Leguminosæ, which break across in several places between the seeds.

In these cases a kind of articulation is produced, by the tissue of the pericarp remaining more delicate in the line of dehiscence, so that it becomes torn by the hygrometric contraction or expansion of the firmer parts above and below, after the fruit has become mature.

Period of Dehiscence.—Dehiscence does not usually take place until the seeds are ripe; but in Mignonette (*Reseda*) the ovary opens before; in *Leontice thalictroides* the ovary bursts very early, and the seed ripens in a naked condition. In *Impatiens* and some other plants dehiscence takes place suddenly with considerable force, the valves separating and rapidly curling up. In *Elaterium* the peduncle separates in a similar sudden way from the ripe fruit, and the seeds are forcibly ejected.

Fruit of Gymnosperms.—In Gymnosperms there is of course no proper dehiscence; but in most cases the carpellary scales of the female cones, which are separate to some extent during fertilization, frequently close up together so as to form an apparently solid body while the seeds are ripening, as in *Pinus*, *Cupressus*, *Thuja*, &c. (fig. 309). The scales open again when the seeds are ripe,

but in some cases not for many years, and in other cases they separate from the axis. In *Juniperus* the scales become succulent. In *Taxus* the solitary ovule is naked; but during the ripening of the seed a succulent cup-like envelope grows up round it.

Forms of Fruit.—The forms of perfect fruit are distinguished by technical names, and in defining them it is desirable to classify them in some way. The classification which conveys the greatest amount of information is that founded primarily on the construction of fruits.

Fruits may be divided first into *free* or *monothalamic fruits*, formed from single flowers, and *confluent fruits*, formed of the blended flowers of an inflorescence. The term *polythalamic* has been conveniently applied to fruits of this latter kind.

Free fruits may be divided into:—1. *Apocarpous fruits*, where the constituent carpels are solitary, or, if more than one, separate; 2. *Syncarpous fruits*, formed of compound ovaries, and consisting of (*a*) *superior fruits* when the calyx is free, and (*b*) *inferior fruits* when the tube of the receptacle or of the calyx is adherent.

Confluent fruits require no corresponding subdivision.

The following are the terms most usually employed, and very many more might be enumerated; but botanists now content themselves with a few well-defined types, and for the rest use such terms as capsular, baccate, &c., to indicate the general nature of the fruit, as more rigidly applied terms are not only cumbersome, but often fail in practice.

Apocarpous Fruits.

Achænium.—The *Achænium* is a small, dry, indehiscent, one-seeded pericarp, tipped with the remains of the style, and with the seed free in the interior, except at the point of attachment.

This fruit is rarely found solitary, as in *Alchemilla*; it usually forms

Fig. 279.

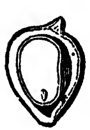


Fig. 280.

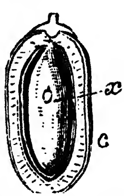


Fig. 281.

Fig. 282.

Fig. 279. Achænium of *Ranunculus* cut vertically to show the seed.
Fig. 280. Section of the fruit of the Date (*Phœnix dactylifera*): *c*, the pericarp; *x*, the embryo imbedded in the horny albumen.
Fig. 281. Circles of follicles of *Sempervivum*.
Fig. 282. Persistent calyx of a Boraginaceous plant, opened to show the carcerulus formed of four indehiscent carpels, separating from each other.

part of a multiple fruit, as in *Ranunculus*, *Geum* (fig. 289), &c., where they occur on a dry receptacle or thalamus, or as in the Strawberry, where they occur imbedded in a succulent receptacle. Achænia are popularly mistaken for seeds, from which they may be known by the stylar beak and by the seed lying loose inside.

The term achænium is often loosely applied to the halves of Umbelliferous fruits (fig. 300), the cocci of Mallows, the *nucules* or *nuts* of Boraginaceæ, Labiatæ, &c. (the *carcerule* of some authors) (fig. 282), and to the *cypselæ* of Compositæ (figs. 283-285).

Fig. 283.

Fig. 284.

Fig. 285.

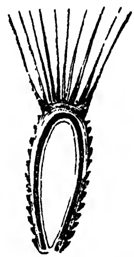


Fig. 283. Cypsela of *Scorzonera*. Fig. 284. Cypsela of *Bidens*.
Fig. 285. Cypsela sliced vertically, to show the seed within.

Drupe.—The *Drupe* is a one-celled fleshy fruit, represented by stone-fruits formed from a single pistil, such as the Cherry or Plum, where the stone is formed by the inner part of the pericarp, and the pulp by the outer part.

In common stone-fruits the drupe is solitary; but minute drupes formed on the same plan are assembled together on the receptacle of the Raspberry and Blackberry (fig. 290). The term drupe is often improperly applied to the compound stone-fruits, like the Cocoa-nut, &c.,—or to the Date, where the stone is formed by the seed alone, and the pulp by the pericarp (fig. 280). Fruits of this general kind are called drupaceous.

Follicle.—The *Follicle* is a simple pod, splitting down the ventral suture only, and bearing the numerous ovules on its margins.

This rarely occurs solitary, but mostly combined with others in a circle, as in *Aquilegia*, *Sempervivum* (fig. 281), &c.; and they are then often coherent at the base.

Legume.—The *Legume* is a one- or many-seeded simple fruit, usually splitting down both sutures, with the placentas on the margins of the ventral suture.

In most cases the *legume* is elongated and pod-like (fig. 286), as in the Pea, &c.; but sometimes it is curved or even spirally coiled like a snail's shell, as in *Medicago* (fig. 287), or lobed and knotted, as in *Acacia* (fig. 288). In *Astragalus* a spurious sutural septum is formed by projection inward of one of the sutures (fig. 252).

The *Lomentum* is a modification of the legume, either wholly indehiscent, or constricted into joints between the seeds and sometimes falling

Fig. 286.

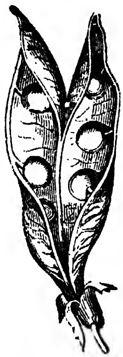


Fig. 287.

Fig. 288.

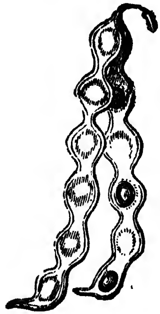


Fig. 286. Legume of Pea, burst.
Fig. 287. *a*, Curled legume of *Medicago sativa*; *b*, of *Medicago orbicularis*.
Fig. 288. Legume of an *Acacia*.

to pieces in these situations, as in *Ornithopus*, *Desmodium*, &c. In the lomentum of *Cassia* (e. g. *Cassia Fistula*) there are many false cross septa.

Fig. 289.

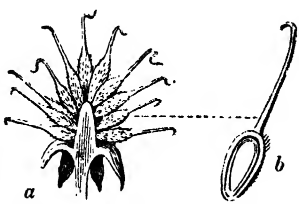


Fig. 290.

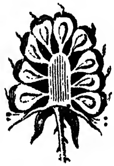


Fig. 289. Multiple fruit of *Geum*, cut vertically (*a*) to show the attachment of the component achænia (*b*) on a dry receptacle.
Fig. 290. Multiple fruit of Blackberry (*Rubus*), cut vertically, showing the spongy receptacle covered with little drupes.

Syncarpous Fruits—Superior.

Caryopsis.—The *Caryopsis* is the one-seeded fruit of the Grasses, composed of two or, rarely, three carpels, which form a dry pericarp inseparable from the seed. In practice it is hardly recognizable from the achene, except in the last-mentioned characteristic.

Samara.—The *Samara* is a two- or more-celled, few-seeded, dry, indehiscent fruit, which has a membranous wing or wings

Fig. 291.

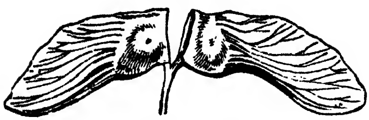


Fig. 292.

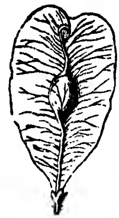


Fig. 293.

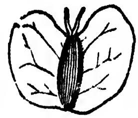


Fig. 291. Double samara of the Maple (*Acer*).
Fig. 292. Samara of the Elm (*Ulmus campestris*).
Fig. 293. Samaroid fruit of the Birch (*Betula alba*).

developed from the pericarp—as in *Acer* (fig. 291), *Ulmus* (fig. 292), and the little fruits of the catkin of the Birch (fig. 293). Practically this may be regarded as one or more achenes with winged pericarps.

Pyxis.—The *Pyxis* is a one- or more-celled, many-seeded fruit, the upper part of which falls off like a lid by circumscissile dehiscence, as in *Anagallis* (fig. 274), *Hyoscyamus* (fig. 294), *Lecythis*, &c. It differs from the capsule merely in its transverse dehiscence.

Siliqua.—This is a two-valved linear pod, the valves of which separate septifragally from a kind of frame, with a more or less perfect false septum (*replum*) stretched across it, the parietal placentas being attached to the frame, as in *Sinapis* (fig. 295), *Cheiranthus*, &c. It is the characteristic fruit of Crucifers.

The *Silicula* (diminutive of the last) is merely a short and broad siliqua, often most expanded in the direction at right angles to the *replum*, the valves sometimes winged—*Thlaspi* (fig. 296), *Capsella*, &c.

When the *replum* is imperfect, it is said to be *fenestrate*; or it may be destroyed altogether. Some siliquas and siliculas do not burst by valves —*Crambe*, *Raphanus*, *Isatis* (fig. 297), &c.

Capsule.—The *Capsule* includes all the remaining kinds of dry fruits, membranous or woody, formed of one-celled or many-celled compound ovaries, which dehisce more or less completely by regular valves, equal in number to or double that of the carpels (*Iris*, *Colchicum*, Caryophyllaceæ, *Digitalis*, *Primula*, &c.), or by pores (*Antirrhinum*, *Papaver*). Its mode of dehiscence may be septicidal,

loculicidal, or septifragal. Fruits of this general character are called capsular.

Fig. 294.

Fig. 296.

Fig. 295.

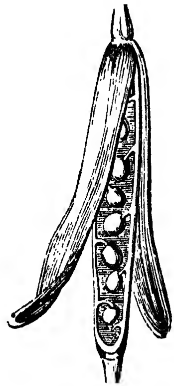


Fig. 297.

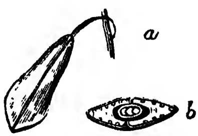


Fig. 294. Pyxis of *Hyoscyamus*, enclosed in the dry calyx.
Fig. 295. Burst siliqua of *Sinapis*, the valves separating from the sutures supporting the replum.
Fig. 296. Burst silicle of *Thlaspi*.
Fig. 297. Indehiscent fruit of *Isatis*: *a*, entire; *b*, a cross section.

Syncarpous Fruits—Inferior.

Glans.—The *Glans* is a hard, dry, indehiscent fruit, spuriously one-celled from suppression, usually one-seeded, seated in a persistent involucre forming a *cupule*. In the Acorn and Hazelnut there is a single gland in each cupule or cup, while in the Beech and Chestnut there are several.

The ovary of the Oak is 3-celled, with two ovules in each cell; but two cells with their ovules, together with one ovule of the fertile cell, are suppressed, and the wall of the ovary (fig. 271) is converted into a bony shell, completely filled by the remaining seed. The ovary of the Birch is also 3-celled, that of the Hazel 2-celled, that of the Chestnut 3–8-celled; and similar suppression takes place. The inferior character of the fruit is marked, especially in the Chestnut, by the remains of the teeth of the calyx on the summit (fig. 216, p. 117). In the Acorn the gland is naked above, seated in a cup; in the Hazel the leafy cupule envelopes it; and in the Chestnut and Beech the spiny cupule encloses several fruits.

Cremocarp.—The *Cremocarp* is a schizocarpous or splitting fruit, consisting of two inferior achenes formed from a two- or

several-celled compound inferior ovary, the cells of which separate when ripe as indehiscent *cocci*. The separate halves of the two-celled fruit of Umbelliferæ are frequently called *mericarps* (figs. 298–300) (*Galium* and many other Rubiaceæ, &c.).

Fig. 298.

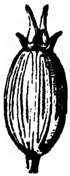


Fig. 299.

Fig. 300.

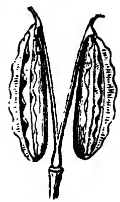


Fig. 298. Fruit of *Œnanthe*, the halves not separated.
Fig. 299. Cross section of the fruit of the Carrot.
Fig. 300. Fruit of Umbelliferæ, the mericarps separated and hanging from the carpophore.

Bacca, or Berry.—The *Bacca*, or true berry, is an inferior succulent fruit, crowned by the withered teeth of the calyx; it is uniformly pulpy, with a thin skin, the numerous seeds being imbedded in the pulp—Gooseberry, Currant, Cornel (fig. 302), &c. The term "*baccate*" is now generally applied to all succulent fruits, whether superior or inferior, which have not a distinct stone like a drupe, as fig. 301.

Fig. 303.

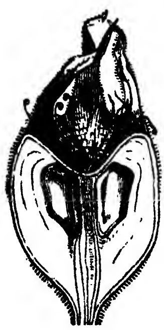


Fig. 301.

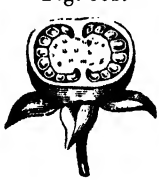


Fig. 302.

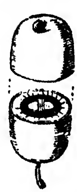


Fig. 304.

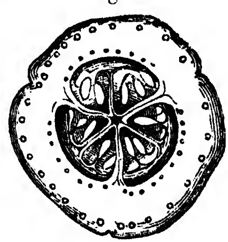
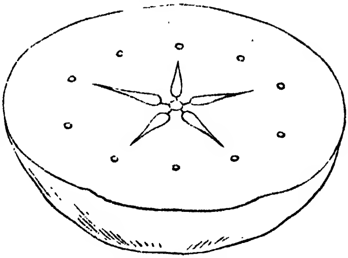


Fig. 301. Nuculanium, uva, or superior berry of *Solanum*, cut across.
Fig. 302. Berry of Cornel (*Cornus mas*).
Fig. 303. Vertical section of the pome of *Mespilus* (Medlar).
Fig. 304. Cross section of the pepo of Cucumber.

Pome.—The *Pomum* (fig. 305) is a compound, many-celled succulent fruit, in which the epicarp is fleshy, while the endocarp forms either cartilaginous linings and partitions to the cells (a "core"), or bony shells around the more or less separated cells—Apple, Quince, Medlar (fig. 303), Hawthorn, &c. The fleshy portion of the pome consists of a dilatation of the upper end of the flower-stalk, in which the true carpels are imbedded.

Fig. 305.



Pome of Apple.

Pepo.—The Gourd is a succulent inferior one-celled fruit, with the seeds on three parietal placentas, imbedded in pulp, which often fills up the cavity; the epicarp is more or less leathery (Cucumber, fig. 304), or thickened and indurated (Gourd).

Infrutescences or Confluent Fruits.

Syconus.—The *Syconus* is a succulent fruit, formed of an enlarged fleshy excavated or concave flowering axis, in which are imbedded numerous separate fruits with dry pericarps. In the Fig the seed-like pericarps are seated on the walls of the internal cavity (fig. 306); in *Dorstenia* they are imbedded in the concave-topped common receptacle.

Fig. 306.

Fig. 307.

Fig. 308.

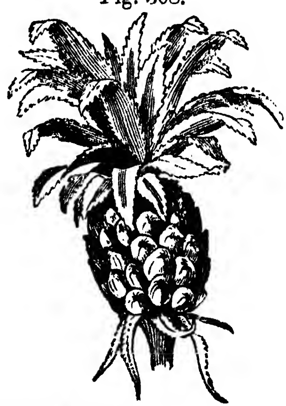
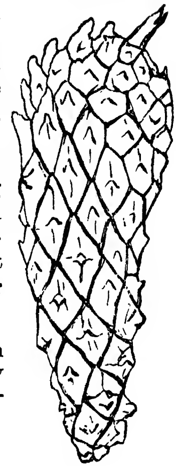


Fig. 306. Vertical section of the Fig (*Ficus Carica*).
Fig. 307. Fruit of Mulberry (*Morus nigra*).
Fig. 308. Fruit of Pine-apple (*Ananassa sativa*).

Sorosis.—The *Sorosis* differs from the foregoing by the substance of the constituent pericarps, formed of the ovaries and floral envelopes of the flowers, becoming pulpy and confluent with each other (*Morus*, fig. 307), and sometimes with the succulent axis of the inflorescence (Pine-apple, fig. 308, Bread-fruit).

Fig. 309.



Strobilus.—The *Strobilus*, or Cone, is the characteristic fruit of the Gymnosperms, consisting mostly of a conical or ovate mass of imbricated scales, with seeds in their axils (or on their borders, *Cycas*), each scale being the development of a single carpel, representing a female flower (*Pinus*, fig. 309).

The *Galbulus* is a kind of cone with few scales, which have their heads thickened and forming the periphery of a somewhat globular mass, dry (*Cupressus*), or sometimes succulent (*Juniperus*, fig. 267).

The Seed.

Formation of the Seed.—The consequence of the fecundation of the ovule is the development of an *embryo* in the embryo-sac (p. 139); and during the maturation of the fruit the ovules are perfected into *seeds*, the essential character of which is, that they are independent reproductive bodies, containing an *embryo* or rudimentary plant at the time when they are cast off by the parent (fig. 311 B, *e*).

Fig. 310.

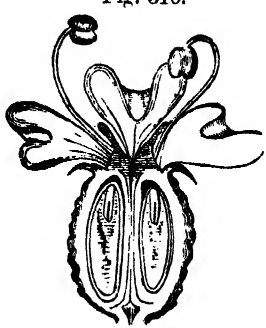


Fig. 311.

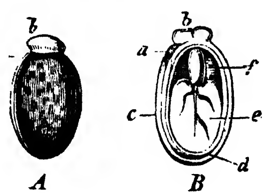


Fig. 310. Section of an Umbelliferous flower, showing the two seeds *in situ*, each containing an embryo at the upper end, imbedded in albumen.

Fig 311. Seed of Castor-oil plant (*Ricinus*): *A*, external view; *B*, vertical section: *a*, *hilum*; *b*, *micropyle*, with an *arillode* around it; *c*, *raphe*, leading to (*d*) the *chalaza*; *e*, *embryo*, with foliaceous *cotyledons*, and *radicle* pointing to the *micropyle*; *f*, *perisperm* or *albumen*.

The seed remains attached to the placenta of the fruit, until mature, by the *funiculus*, from which it ultimately separates by an articulation, so that a scar is left, called the *hilum*.

The *direction* and position of the seeds in the cells of the fruit, as well as the modes of curvature, indicated externally by the relative positions of the hilum (fig. 311, *a*), micropyle (*b*), chalaza (*d*), and raphe (*c*), are the same as in the case of the ovule; and the same terms are made use of in describing their peculiarities.
The face of a seed is the side or edge turned towards the placenta from which it arises.
The direction of seeds may differ from that of the ovules, by alteration in the shape of the ovary, abortion of ovules, &c. It may be noted that anatropous ovules normally have the raphe *next* the placenta if *ascending* or *suspended*, so that the raphe indicates the face.

Parts of the Seed.—The seed consists of the proper *body* of the seed and its integuments, to which in some cases are added appendages of various kinds.

The outer coat of the seed, called the *testa*, completely encloses it, marked, however, by the microscopic orifice of the *micropyle*, and by the *hilum*, or scar of the funiculus. The testa presents the greatest possible variety of conditions of texture, from membranous, horny, woody, or bony hardness, on the one hand, to a leathery or soft, pulpy condition on the other. The dry forms frequently exhibit beautifully regular markings, such as minute ridges, reticulations (Poppy, *Silene*, &c.), spines (*Stellaria*, &c.); or the margins are produced into sharp edges or broad wings (*Bignonia*, *Pinus*, fig. 312); or it bears a crown of hairs, or *coma*, at one end, as in *Epilobium*, *Asclepias*, &c.; or it is completely covered with long hairs, as in the Cotton plant: while in various Polemoniaceæ, Labiatæ, &c. (*Collomia* &c.) it is clothed with microscopic hairs, which expand elastically and dissolve into a kind of mucilage when wetted. Sometimes the testa is loose, and forms a kind of sac around the body of the seed, as in Orchidaceæ, *Pyrola*, &c.

Fig. 312.

Winged seed of Pine.

The *inner integument*, the *tegmen* or *endopleura*, is not generally distinguishable; when it is, it is usually whitish and delicate.

The reference of the integuments of the seed to their elements in the ovule is a subject of great complexity, since there appear to be no rules as to what regions of the ovule, from the nucleus outward, shall remain distinguishable or enter into the composition of the coats. The testa is commonly formed of the *primine* and *secundine* (p. 137) of the ovule conjoined. The tegmen seems to originate sometimes from the secundine, sometimes from the substance of the nucleus, &c. Small indehiscent fruits, such as the achænia of *Ranunculus* (fig. 313) or of Borages (fig. 282, p. 145),

are liable to be mistaken for seeds when detached; they are known by the remains of the style, and by the complete seed with its proper coat being distinguishable on opening the pericarp (fig. 313).

Fig. 313.

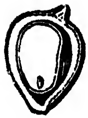


Fig. 314.

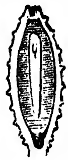


Fig. 315.

Fig. 316.

Fig. 313. Vertical section of an achænium of *Ranunculus*, showing the seed within the pericarp and with a minute embryo in the albumen.
Fig. 314. Section of the seed of *Typha*, showing the straight embryo in the axis of the perisperm or albumen.
Fig. 315. Section of the caryopsis of Wheat, showing the abundant perisperm, *a*, with the embryo, *b*, at the base, outside.
Fig. 316. Section of the seed of *Iris*, with the embryo enclosed in the perisperm.

Enations from the Seed.—A considerable number of seeds possess a coat or appendage distinct from the proper integument, and produced *entirely during the development of the seed from the ovule*—that is to say, after the fertilization of the latter. These additional structures are frequently fleshy when mature, as in the Spindle-tree, *Euonymus*, *Podophyllum*, &c. The older authors called all the forms by the same term, *arillus*; recent authors distinguish the *true arillus*, which grows up over the seed from the funiculus, like the primine and secundine, as in *Nymphæa*, Passion-flowers, &c., from the *arillode*, which originates at or near the micropyle, and grows down more or less over the testa, as in *Euonymus* (where it forms a pulpy coat), in *Euphorbia*, *Ricinus* (fig. 311), *Polygala*, &c.

The *mace* of the nutmeg is an arillus, adhering both to the hilum and micropyle.

The appendages which grow from the raphe, in *Chelidonium*, *Asarum*, *Viola*, &c., are sometimes called *strophioles*.

The body of the seed is composed either of the *embryo* alone, or of the embryo imbedded in a mass of tissue, called the *perisperm*, or *albumen* (figs. 313–320). Seeds wherein the embryo is immediately invested by the integuments are commonly called *exalbuminous* or *aperispermic* (figs. 321 & 323). Where *perisperm* exists, they are called *albuminous* (figs. 313 &c.).

The term *albumen*, founded upon the functional analogy with the albumen or white of an egg, is very inconvenient, as it has a distinct chemical sense, in which it is frequently used in the chemical questions of vegetable

physiology; and therefore the word *perisperm* is preferable. All seeds in their rudimentary condition contain perisperm; but as the embryo grows it is often absorbed, so that in the ripe seed it is no longer perceptible. It is considered to be analogous with the prothallus of the higher Cryptogams.

The Perisperm varies very much in both quantity and in texture —in proportion to the relative magnitude attained by the embryo (figs. 313 & 320), and in consequence of the different mode of

Fig. 317.

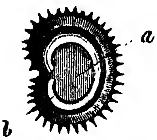


Fig. 318.

Fig. 319.

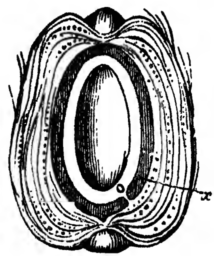


Fig. 317. Section of the seed of *Lychnis*, with a peripherically curved embryo, *b*, surrounding the perisperm, *a*.
Fig. 318. Section of the seed of *Piper*, showing the embryo in a separate sac at the apex of the perisperm, which latter is hollow in the middle.
Fig. 319. Section of the fruit of the Cocoa-nut Palm, showing the fibrous epicarp, the woody endocarp (x) enclosing the hollow perisperm, in which lies the minute embryo.

development of the cellular tissue and its contents in different cases.

The texture or consistence of the perisperm is termed *mealy* or *farinaceous* when it may be readily broken down into a starchy

Fig. 320.

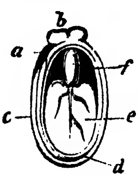


Fig. 321.

Fig. 322.

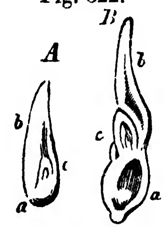


Fig. 320. Vertical section of the seed of *Ricinus*: *a*, hilum; *b*, micropyle; *c*, raphe; *d*, chalaza *e*, embryo; *f*, perisperm.
Fig. 321. Aperispermic dicotyledonous seed of a Bean, with the coats removed: *a*, radicle; *b'*, *b''*, cotyledons (separated to show the plumule, *c*).
Fig. 322. Monocotyledonous embryos removed from the perisperm, vertically sliced: A, of *Calla palustris*; B, *Avena* (Oat): *a*, radicle; *b*, cotyledon; *c*, plumule.

powder (as in Corn-grains &c.); *oily* when it is composed of soft

tissue loaded with fixed oil (as in the Poppy and Cocoa-nut); *mucilaginous* or fleshy when it is tougher and swells up readily when wetted (as in the Mallow); *horny* when hard and more or less elastic (as in Coffee, *Galium*, *Iris*, &c.).

The perisperm is usually a uniform mass; but in *Nymphæa*, Piperaceæ (fig. 318), *Canna*, and some other plants the embryo is contained in an inner central compartment or sac (sometimes called the amniotic sac), so that the perisperm is here double. The enclosed portion is sometimes called the *endosperm*; the development of this will be described in the Physiological part of this work.

The uniformity of the perisperm is also destroyed in some seeds by a peculiar lobulated condition of the outer portion, the sinuosities being filled up and enclosed in an inseparable layer of different-coloured tissue, giving a marbled appearance; this, which is seen in the Nutmeg, is called a *ruminated* perisperm or albumen. In the Cocoa-nut the perisperm is hollow when mature, containing the so-called milk (fig. 319).

The Embryo.—The *embryo*, or rudimentary plant contained in the seed, ordinarily possesses, when the seed is mature, all the essential organs of vegetation, namely root, stem, and leaves, although in a few cases the leaves are undistinguishable; while in others the embryo is a mere cellular nodule in the ripe seed, as in Orchidaceæ and Orobanchaceæ. The embryo is the result of the fertilization of the germinal vesicle or *oosphere* contained in the embryo-sac (p. 139).

Parts of the Embryo.—The end of the embryo usually pointing to the micropyle is the *radicle* (figs. 320–323, *a*) or rudimentary root, continuous with the lower end of the axis which terminates at the other end in the *plumule* (figs. 321–323, *c*) or rudimentary terminal bud. The axis itself is sometimes very short, being a mere "collar" between the base of the seed-leaves and the radicle; but, in some cases, it is developed into a well-marked *hypocotyledonary axis* or *tigellum*, distinguishable from the radicle by its cylindrical form (or, if conical, the point of the cone is upwards). The rudimentary leaves, called *cotyledons* (figs. 321–323, *b''*, *b'*, *b*), differ in number in the two great classes of Angiospermous Flowering plants, since in the Dicotyledons there are two placed face to face at the upper end of the axis, with the plumule between them (fig. 321); and in Monocotyledons only one exists (or the rudiment of another on a different level), and this is more or less completely rolled round the plumule, like the sheath of the leaf in Grasses (fig. 323).

The embryos of the Gymnosperms are either dicotyledonous, as in *Cycas*, *Taxus*, *Juniperus*, &c., or really or apparently *polycotyledonous*, as in *Pinus* (fig. 324), where it is said that the seeming whorl is formed of two deeply divided cotyledons.

Direction of the Embryo.—The embryo, whether covered only by

the coats or imbedded in perisperm, exhibits many varieties in the relative position of its parts: thus it may be *straight* (fig. 314), *curved, arcuate*, or *hooked* (fig. 325), *spirally coiled* (fig. 326), or *folded*; in

Fig. 323. Fig. 324. Fig. 325. Fig. 326.

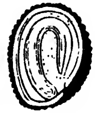


Fig. 323. Aperispermic Monocotyledonous seed of *Potamogeton*, with the coat removed: *a*, radicle; *b*, cotyledon; *c*, plumule.
Fig. 324. Embryo of *Pinus*, extracted from the perisperm, and the cotyledonary lobes separated.
Fig. 325. Vertical section of the seed of *Atropa Belladonna*.
Fig. 326. Vertical section of the seed of the Hop (*Humulus*).

the last case the radicle may be folded against the back of one of the cotyledons (*incumbent*, fig. 327) or against their edges (*accumbent*).

The *cotyledons*, which are usually of fleshy texture, and vary much in form, degree of expansion, and solidity in different cases, are occasionally rolled or folded up like leaves in leaf-buds (figs. 328 & 329); and these are described by the terms defined above under the vernation of leaves (p. 73). They are sometimes *foliaceous*, as in *Convolvulus* or *Ricinus* (fig. 320), &c. The fleshy kinds occasionally cohere very firmly in Dicotyledons in the mature state; and they are sometimes of unequal size, as in *Trapa natans*.

Fig. 327.

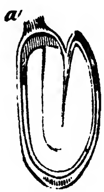


Fig. 328.

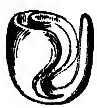


Fig. 329.

Fig. 327. Vertical section of the seed of *Erysimum*: *a*, funiculus.
Fig. 328. Dicotyledonous embryo extracted from a Turnip-seed.
Fig. 329. Dicotyledonous embryo extracted from the seed of the Maple (*Acer*).

Generally the cotyledons form the greater part of the embryo, as in the Bean (fig. 321); but sometimes they are very small or undistinguishable. They usually die away, but in *Welwitschia* they remain to form the only leaves the plant has.

Relative Position of the Embryo.—The embryo may be in the very centre of the perisperm (*Polygonum*), *excentric*; completely external (Grasses, fig. 315); curved round the outside *peripherical* (*Lychnis*, fig. 317). The radicle generally points to the hilum (*homoblastic*), rarely away from it (*enantioblastic*).

PART II.

SYSTEMATIC BOTANY.

CHAPTER I.

PRINCIPLES OF CLASSIFICATION.

Sect. 1. SPECIES AND GENERA.

Systems of Classification.—In throwing plants together into groups, two methods may be adopted, constituting respectively an *artificial* or a *natural* system of classification. In the former, the only object is to arrange or place objects in such order that we may find them readily by some prominent mark, in the same manner as words are arranged alphabetically in a dictionary. In a Natural Classification, the object is so to combine our materials that the things brought closest together shall have the greatest possible agreement; from which it results that a knowledge of all the peculiarities of one carries with it the knowledge of *most* of those of its neighbours, and enables us, from the observation of a portion of the characters of a given kind, to foresee the rest. According to the derivative theory a group is natural in proportion to the accuracy with which it expresses the degree of relationship of the members of the group to each other, and of one group to its fellows. If there is no real kinship the resemblance is only superficial, and the classification therefore artificial.

Species.—Systematic Botany is founded upon the real or assumed existence of distinct *kinds* or *species* of plants—a notion which of course belongs not to science exclusively, but is a part of the common experience of the world. But there is a great difference, practically, between the kinds of things accepted in the ordinary affairs of life and the kinds admitted in science, more especially in the Biological sciences.

There is another fact of daily experience which is of primary importance in reference to this point; that is, the circumstance that plants produced from seeds most commonly resemble in all important respects the parent plant from which the seeds were derived, and this through an indefinite number of generations; from which it follows that kinds or species of plants are regularly reproduced by their seeds.

The definition of a species can only be considered as arbitrary; but for practical purposes it may be said that a species consists of those individual plants which agree in all their important and constant characters, in the same way as do individuals of analogous structure, which we know to have descended through a number of generations from a common stock, and which therefore may be assumed to have been produced through seed from an original individual, or pair of individuals, of a distinct kind. To these may be added the assertions that individuals of the same species may be cross-fertilized, to the improvement rather than the detriment of the fertility of their seeds, and that they are affected in a generally similar manner by external agencies.

Diversity of opinion still exists amongst naturalists as to the origin and fixity of species. On the one hand it is assumed that every distinct species originated in a distinct creation of that form, which has been perpetuated, with its essential characters unchanged, through succeeding generations. It is usually added by the same school that, as regards plants, every species originated from a single prototype, or a pair of parents where the plant is diœcious.

On the other hand, it is contended by most modern naturalists that species were not necessarily created as we now see them, but that existing species are the lineal descendants of those that have gone before, and more or less modified in course of time by varying circumstances, such as inherent tendency to vary, the effect of external agencies, and the competition of other forms. This notion involves the conclusion that species are not absolutely invariable.

Varieties.—Species are distinguished by those characters which under present circumstances are constant so long as the conditions under which they exist remain unchanged; but individuals may possess other *additional* characters of less importance, which are inconstant. Even as in the human species we find every individual possessing certain peculiarities, so even in almost to the lowest of created beings do we find what is called an idiosyncrasy, and individual character, chiefly depending, in the vegetable kingdom, upon the conditions under which they have grown up. We often find seeds from the same parent producing individual plants differing in the colour, size, and number of their flowers and of their vegetative organs, according to the conditions of climate and soil to which we submit them. Very often, moreover, we find these differences displaying themselves under what appear to us identical conditions, as is particularly the case with many of the favourite "florist's flowers"—such as the *Pelargonium*, *Fuchsia*, Pinks, Asters, &c.,

which "sport" out into numberless varieties when raised from seed under highly artificial conditions. The occurrence of such variations is less common and, when it occurs, generally less marked in wild plants, as might naturally be expected, from the likelihood of wild plants maintaining their footing best in a position where the conditions are most natural to them; but we do find remarkable cases of variation in many wild species, as of colour in the common Milkwort and the Columbine (*Aquilegia*); but most of those kinds which exhibit the tendency now and then in a wild state, become extremely variable under culture. Some of the variations are dependent simply upon modifications of the cell-contents of certain tissues, as in the commonest of all variations, those of colour, and in the not uncommon appearance of white patches and streaks ("variegation") on the leaves. Other variations are teratological, and result from the over-stimulation of the vegetative system, causing the reproductive organs to degenerate (of which the ordinary "doubling" of flowers by the degradation of their stamens into petals is an example)—or, *vice versâ*, the application of stimuli at particular epochs, producing remarkable development of flower or fruit. All these variations, more especially those involving serious teratological changes, tend to disappear. Common variations, of slight importance, mostly die out at once in the descendants through seed, especially if the conditions are varied; serious departures from the typical structure (teratological variations) lead to barrenness and incapability of continuing either the variety or the species by seed.

It is important to note here a fact which will be more minutely examined in another place, namely, that although the peculiar characters of varieties are commonly lost in seeds, the peculiar form is capable of indefinite propagation by vegetative multiplication through cuttings &c., the special idiosyncracy being possessed in common throughout all the leaf-buds, both while forming part of the parent and after they have been detached from it to form new plants, grafts, &c.

A certain number of species which vary more or less in a wild state exhibit a remarkable peculiarity under systematic cultivation. By strictly maintaining a certain set of conditions, varieties originating accidentally or through intentional treatment are made to manifest their additional peculiarities so strongly, that they transmit the tendency to present similar peculiarities to their seeds; and such transmission goes on for an indefinite number of generations, provided the requisite external conditions are kept up. In this way arise what are called *Races*, series of individuals connected by common characters and by inheritance, like species; but, unlike them, liable to lose, in one or a few generations, under change of conditions, part or all of the essential characters by which they are distinguished. We have examples of such races in most of our esculent vegetables, especially in the many varieties of form, more or less permanent, derived from the wild Cabbage (*Brassica oleracea*).

These, together with *Hybrids*, or the produce of cross-fertilization between individuals of distinct species, will be referred to again among the phenomena of the Physiology of Reproduction. The determination of the limits of species is greatly obstructed in many cases by the frequent occurrence of varieties, and more particularly of races—to which hybrids add another complication, probably of less importance than many modern authors suppose. It appears probable that the number of real species is

far smaller than is usually supposed, and that many races, and a large number of frequently recurring varieties, hold a place in our existing lists of species. The varieties and races above mentioned are considered under the development hypothesis as the initial stages in the formation of new species. If these variations are of such a nature as to enable the plant to adapt itself better to the conditions under which it lives, or to sustain itself in the battle of life with other organisms, then they will be perpetuated—become more constant, and ultimately attain such a degree of relative constancy or invariability as to be classed as species.

Genera.—Whenever we examine a large assemblage of distinct species, we shall find that certain of these agree with certain others more closely than with the rest; so that we may parcel them out into groups, in each of which we shall find an agreement in a number of common characters, by which it is also distinguishable from the other groups. Generally speaking, we shall find that we can place together a number of species agreeing closely in the essential plan of construction of their *floral organs*, while they differ in the forms and duration of their *vegetative organs*, &c. Groups of this kind are called *genera*; and the notion of a *genus*, like that of a species, is not only common to all departments of human knowledge, but is also existent in the language of common life in its special natural-history sense, only requiring for scientific purposes to be more strictly defined. In every language we find *generic* names applied to plants, such as Willow, Rose, Violet, and a hundred others, each of which terms is indicative of a group of kinds or species, more or less extensive in different cases, corresponding exactly in its logical value to the *genus* of the botanist.

Some of these groups are characterized by very striking peculiarities, so that even the genera of vulgar language correspond very nearly with those of the botanist; but in the generality of cases the popular collective names are applied on superficial grounds of resemblance, and include widely diverse species. For example, the term Violet is made to bind together not merely the common scented and other true Violets, but the Dame's Violet (*Hesperis*), a plant of the Cabbage family, the Calathian Violet (*Gentiana Pneumonanthe*), a true and characteristic Gentian, the Dog's-tooth Violet (*Erythronium Dens-Canis*), a plant of the Lily family, &c.; while the term Rose is extended from true Roses to *Cisti*, or Rock-roses, Rhododendrons, Alpine Roses, &c. It is obvious here that there can be no near "blood relationship," if we may so term it, between these so-called Roses, &c. The classification of all these forms having only superficial resemblance to each other is a purely artificial classification. Still some genera are characterized in a sufficiently marked way for most of their constituent species to be recognized as such pretty readily, after a very small amount of attentive examination, as, for example, true Roses, Willows, Lilies, &c.; and we call such genera, including species of a very marked similarity, "natural genera," thus indicating the closeness of the band that ties them together. On the other hand, the principle of combination which accords with the intuitive classification in those

natural genera leads to the establishment of other genera wherein the species seem at first sight to differ widely, of which we could not have a better example than in the genus *Euphorbia,* where our native species are inconspicuous herbs, while the tropics afford species with large spiny Cactus-like trunks, &c.

Moreover the carrying out of the same principle leads in certain cases to the generic separation of species which present close agreement in their general characters, but are distributable into a number of groups characterized by very decided morphological diversities in important parts of their floral organs. Thus, in the Umbelliferæ, the Compositæ, the Grasses, and some other families, we separate generically species which have a great resemblance in the majority of their characters. This happens especially in what are called *very natural families* of plants, large assemblages of genera so evidently connected with each other by the presence of some very marked peculiarity, such as the Umbelliferous inflorescence, the Papilionaceous corolla of the Leguminosæ, the Capitulous inflorescence of the Compositæ, the peculiar spikelets in the Grasses, &c., that no doubt can be entertained as to their lineage. On the other hand, the "natural genera" occur mostly where the character of the natural family is more lax and flexible, as in the Ranunculaceæ, Rosaceæ, &c.

In the present state of knowledge it must be admitted that a very large portion of our generic distinctions are arbitrary, and that the species included in some genera agree together much more closely than those combined under other generic heads. At the same time it cannot be doubted that some genera are really far more extensively represented by species than others; so that the mere number of kinds included in a genus is to be totally neglected in a natural classification; and many recent authors have done disservice to science in general by splitting up large natural genera on slight characters for the convenience of systematists. It is far more instructive to keep together the members of large natural genera, like *Ficus, Erica, Begonia,* &c., than to subdivide them under names which disguise their relations; and the convenience of systematists may always be sufficiently regarded by the establishment of *sections* in extensive descriptive works.

Genera are groups of species associated on account of agreement in the essential characters of their floral organs; but here, as elsewhere in nature, variations from our abstract types must be admitted. Some undoubtedly natural genera include species with their floral organs varying in certain particulars more than is usual in groups associated under a common type, somewhat as certain species admit of a wider range of variation than others. Here, again, physiological characters become of value; and as in species we regard the fertility of the seeds produced by unlimited cross-breeding between the varieties as a proof of these being individuals of the same species, so with regard to genera it is commonly held that a generic connexion between diverse species is indicated by the capability of producing *hybrids* by cross-breeding. These true hybrids produced between distinct species of the same genus are often barren, or only breed with individuals of one of the parent

species, which soon eliminates the cross, and leads to a complete reversion to that species.

The physiological test is consonant with morphological evidence. Individuals of the same species are capable of indiscriminate fertilization because they are exactly alike in all essentials of structure. In hybrids produced between two species of a genus, the parents agree sufficiently in structure to allow of their producing a few fertile seeds; but the plants raised from these seeds contain two contradictory impulses, which so far prevent the perfection of their organization that they either remain barren or a dissociation of the mixed characteristics occurs with, it may be, their ultimate entire extinction.

Origin of Species—Selection.—Supposing species to have originated from a few primordial forms, from which all existing species have been derived, just as individuals may be traced back to a common parent stock, the question then arises as to what causes have produced the modifications. Where, on this hypothesis, there were originally a few, or perhaps a single primordial form, to which all then existing individuals might have been referred, there is now an infinite number of forms both in the animal and vegetable kingdoms. How have these arisen? To this question the answer given by various naturalists has been different.

By some the variations have been attributed to the influence of external conditions; by Darwin to an innate tendency, producing variations of structure, some of which, under given circumstances, would be favourable to the progress and development of the individual, and others not so. In the battle of life, the struggle constantly going on in animated nature, those variations most advantageous to the organism in its competition with others would be preserved by "natural selection," while other variations of less advantageous character would be obliterated or not perpetuated. Hence the victory would be to the strongest; the weakest would go to the wall, and the result would be, in Mr. Spencer's language, "the survival of the fittest." It will thus be seen that on this hypothesis species are not considered immutable, and variations, especially such as are advantageous to the organisms, are regarded as the starting-points of new species. With reference to these points the student will do well to bear in mind that these and kindred speculations are not to be treated as dogmas or creeds, but as means to an end, and that end the more perfect knowledge of the origin and relation of existing forms. Any hypothesis or theory which will serve to correlate and bind together a number of otherwise isolated facts and explain their interdependence, is valuable not only for what it effects at the time, but as a focus around which other facts may in future be gathered. That hypothesis is best which serves to give a rational explanation of the largest number of observed phenomena of the greatest importance. Tried by this test, the Darwinian hypothesis, or, rather, the theory of evolution, has great advantages, and presents on the whole fewer difficulties and less inconsistencies than the older hypothesis of separate creation of each species. Particularly does this seem true in the case of the subject now before us —the classification of plants. The admission of the principle of filiation and genealogical descent gives the natural system of classification a clearer claim to its title of "natural" than it had before, supplies the explanation

of a vast number of phenomena otherwise inexplicable, and offers plausible and valid reasons for the existence of facts and processes that were previously considered either unintelligible or purposeless modifications of an assumed structural type. The portion of Mr. Darwin's hypothesis which has perhaps received the least amount of assent has been that relating to natural selection. The idea was based on that artificial process of selection by means of which man has been enabled progressively to improve and perpetuate the different forms of domestic animals and cultivated plants. In the latter case the horticulturist is ever on the look-out for variations. If he sees one that suits his purpose, such, for instance, as a plant producing larger flowers than ordinary, he does all that he can to perpetuate that variety by carefully selecting seed from it, at the same time that he destroys or neglects other less desirable variations. In this manner, after a time, the selected variety becomes "fixed," and a "race" is formed. On the Darwinian hypothesis a selective process is supposed to occur naturally, similar to that employed by the gardener or agriculturist as just explained, such selection or elimination resulting, as before said, in the survival of the fittest.

Sect. 2. Nomenclature.

Names of Plants.—The Terminology of Botany establishes rules for naming the parts or organs of plants, and the different characteristics which those organs present. Nomenclature deals with the naming of plants themselves as members or parts of the Vegetable Kingdom; and it furnishes the rules for naming the kinds of plants, and the various groups or assemblages in which they are associated in our systematic classifications of kinds.

The primary rule in botanical (and zoological) nomenclature as laid down by Linnæus is, that *every species shall have a particular name, compounded of a substantive and an adjective* (or substantive used adjectively), *whereof the former indicates the genus, and the latter the species.*

This rule of naming may be compared with the common usage of surnames and christian names—the former indicating the family to which a man belongs, while the latter admits of his being spoken or written about without the necessity of adverting, except for special purposes, to his personal peculiarities or his relationship to the other members of his family.

These scientific names of plants were originally established in Latin, because Latin was the general language of science at the time they were introduced; and they will be retained with advantage so long as diversity of language exists, since they ensure to all plants and animals names which have universal acceptation, and which, like the Arabic numerals 1, 2, 3, &c., are equally comprehensible to the educated of all nations, and, moreover, they are more definite and precise in their signification than ordinary vernacular appellations.

Generic Names.—The substantive names of genera have been and are still formed very arbitrarily, and without any generally recognized principle.

All those which have been identified as known to the ancients are called by their classic names, such as *Prunus*, *Myrtus*, *Quercus*, *Thymus*, &c., the etymology of which is more or less obscure in various cases. A very large proportion of modern generic names are founded upon combinations of Latin and, more particularly, Greek words indicating some obvious external peculiarity, or some property possessed, or supposed to be possessed, by the plants; but the application of this principle has often been carried out without accurate knowledge and without happiness in selection, so that many such names are but little characteristic, and would often apply more correctly to other genera. Those, on the contrary, which are well chosen afford a certain assistance to the memory; examples of such names, founded on structure, occur in:—*Lithospermum*, so called from its stony fruit (or supposed seed); *Campanula*, from its bell-shaped corolla; *Sagittaria*, from its arrow-shaped leaves, &c.: on qualities, in *Glycyrrhiza* (Liquorice), from its sweet rhizome; *Rubia* (Madder), from yielding a red dye; *Lactuca* (Lettuce), from its milky juice, &c.: or on accustomed station, as *Arenaria*, *Epidendrum*, &c.: others have derived their names from supposed medicinal powers, such as *Pulmonaria*, [illegible]

Another large class of generic names is founded on proper names either of mythological or real personages, more especially distinguished botanists, to whom the genera are dedicated. Linnæus drew largely upon classical mythology and legendary history as a ready source of diverse names for the many newly defined genera he had to deal with; and the names *Iris*, *Artemisia*, *Amaryllis*, *Narcissus*, &c. stand out strongly in their euphony from most of those founded on modern names; such names, however, as *Linnæa*, *Lobelia*, *Dioscorea*, *Magnolia* go far to rescue the principle of naming genera after botanists and their patrons from the opprobrium brought upon it by such as *Schumacheria*, *Schweyckherta*, *Razoumowskia*, *Eschscholtzia*, and the like, and will probably be preferred by most persons even to such "characteristic" names as *Pleuroschismatypus*, *Oxystophyllum*, *Pachypterygium*, *Glischrocaryon*, &c.

In face of these last, the pseudo-Latin barbarisms *Thea*, *Coffæa*, *Bambusa*, which preserve the original native names of plants, become no longer uncouth.

Specific names are always either *adjectives*, or *substantives used adjectively*. When they are adjectives, they must of course be made to agree with the substantive; and it may be recalled to recollection that in Latin all names of *trees* are *feminine*, whatever may be the termination.

In the majority of cases, the specific names are selected on similar grounds to the generic. Attempts are very commonly made to render the name characteristic, a proceeding which in many cases affords a certain advantage; but when, on the contrary, it is carried out in im-

perfect acquaintance with the species of large genera, it leads to confusion. Sometimes these names indicate the character of the *leaves*, as in *Tilia grandifolia* and *parvifolia*, or the existence of a definite number, as in *Platanthera bifolia*, *Paris quadrifolia*, &c.; or the character of the *inflorescence*, as *Butomus umbellatus*, *Bromus racemosus*, &c. Or the "habit" of a species is indicated by such adjectives as *major*, *minor*, *scandens*, &c.; or its duration, as by *annua*, *perennis*, &c.; and in some cases comparisons with other plants are marked, as in *Ranunculus aconitifolius*, *Acer platanoides*, &c.

Generally speaking, the colour of flowers is too variable for specific distinctions; but nevertheless many species are named from their usual or constant colour, as *Gentiana lutea*, *Lamium album* and *purpureum*, *Digitalis purpurea*, &c.

Station, *i. e.* kind of soil or place inhabited by a plant, is another source of names, as *arvensis* (common on ploughed land), *agrestis*, *hortensis* (on cultivated ground generally), *pratensis* (in meadows), *sylvestris* or *sylvaticus* (in woods), *palustris* (in swamps), *aquaticus* (in or about water), and *sativus*, a term commonly applied to kinds regularly cultivated from seed. Most of these terms are applied vaguely, and a similar want of accuracy in the implied idea affects many of the names founded on the places where plants have been first observed, such as *Silene gallica*, *Stachys germanica*, *Genista anglica*, &c., none of which are peculiar to the countries named, though they may, in the first instance, have been considered to be so.

Such names as *odorata*, *suaveolens*, *fœtida*, &c., expressing marked qualities, were formerly much used; and the adjective *officinalis* is found applied to a host of plants formerly valued by the herbalists for some supposed medicinal or economical property.

Substantive names used adjectively are mostly names of abolished genera, retained in association with the new generic term, as *Ranunculus Flammula*, *Pyrus Malus*, *Matricaria Chamomilla*, *Prunus Cerasus*, &c.,—these old generic terms being in a few cases double, as *Adiantum "Capillus-Veneris," Lychnis "Flos-cuculi,"* &c. Or substantive proper names are used in the genitive case, as *Limnocharis Humboldtii*, *Viola Nuttallii*, *Galium Vaillantii*. The dedication to distinguished persons may, however, be effected by adjectival terms, as *Salix Doniana*, &c., the use of the genitive noun being more strictly appropriate when it is the name of the discoverer or first describer of a species, the termination *ana* conveying a mere compliment and not necessarily implying that the person to whose name it is affixed had any thing to do with the particular plant in question.

Authorities for Names.—If the rules of scientific nomenclature were strictly enforced under the direction of a single authority, each plant would have but *one* name (composed of the generic and specific appellations), and this name would be indissolubly and unequivocally connected with the idea of the peculiar species. But it happens practically that such is not the fact, and this for reasons necessarily affecting various cases. Not unfrequently it happens that a plant possesses more than one *specific* name, which may arise from an author naming it a second time, through entire ignorance of its having been previously observed, or from his erroneously supposing a particular form to be distinct from the already known and named species. Almost as frequently in the present day do

we find a distinctly recognized species denominated by more than one *generic* name, while the specific appellation remains the same, this ambiguity arising from difference of opinion as to the limits of genera, and consequently as to the group to which particular species are to be referred.

To ensure accuracy, therefore, it becomes necessary, whenever the name of a plant is mentioned in a scientific work, that the *authority* for the name (that is, the author who originated it, or whose peculiar application of it we adopt) should be indicated. This is done by subjoining an abbreviation of his name. Thus, *Bellis perennis*, Linn., or L.; *Inula Conyza*, DC.; *Pulicaria vulgaris*, Gaertn., signify that we mean the species which were defined under these names by Linnæus, De Candolle, and Gaertner, respectively. In like manner it is requisite, in the majority of cases, where the name of a genus is mentioned, to indicate the authority, since many of the older genera of Linnæus and others have been broken up into a number of groups, and the original name restricted to one of these more limited assemblages.

Synonyms.—The superfluous or incorrect names which exist in many cases cannot be neglected where they have once acquired a certain currency, because a certain amount of existing knowledge is connected with these names in the works of the writers who have used them. Hence arises the necessity of enumerating the *synonyms* of plants. The citation of synonyms is of course unnecessary in general cases, where the names of plants are incidentally mentioned, so long as the authority for the name is given; but in Systematic works, such as descriptions of the plants of a country or province, or monographs upon particular groups of plants, it is part of an author's duty to ascertain and indicate all the names which have been applied to the particular forms, and the exact senses in which different names have been employed. The synonyms subjoined to a specific name may indicate:—1, that the same species has received different names from different authors; 2, that a selected specific name includes the several supposed or real species enumerated under it; 3, that the species has been removed from a genus to which it was formerly referred; 4, that a particular view is taken both of the generic and specific value of a plant concerning which opinions have varied in both particulars.

The following examples may serve to illustrate this:—

1. The name *Galium verum*, L., has simple priority and therefore preference over *G. luteum*, Lamarck, indicating the same species, which was accidentally or erroneously named by the latter author *after* Linnæus had given it an appellation.

2. *Agrostis alba*, L., includes *A. compressa*, Willd., *A. gigantea*, Roth, *A. stolonifera*, L. (in part), &c.; these latter have been mistakenly separated from it, or subsequently named without knowledge of the identity.

3. *Castanea vulgaris*, Lam., is now substituted for *Fagus Castanea*, L., as the genus *Castanea* is now regarded as distinct from *Fagus*. In many

cases we find a distinct generic name given as a synonym where it is really more recent, but is rejected in favour of the older on the ground that the more recent generic separation is not approved of; for instance, *Apargia autumnalis*, Willd. (*Oporinia autumnalis*, Don).

4. *Catabrosa aquatica*, Beauv., is named in diverse works *Aira aquatica*, L., *Molinia aquatica*, Wibel., *Poa airoides*, Koel., *Glyceria aquatica*, Presl, &c.

The multitudinous synonyms which fall under the last category are attributable to the excessive tendency of modern writers to multiply genera on slight grounds. Such minor subdivisions are far better restricted to extensive systematic works, on the plan adopted in De Candolle's 'Prodomus,' providing them with sectional names for the exclusive use of systematists, and preserving the more general name for common purposes.

Nomenclature of Varieties.—The varieties of species are noticed in descriptive works when of frequent occurrence, and then are either simply indicated by the letters of the Greek alphabet, or have an additional adjective name like the species, which plan is especially followed in lists of garden varieties. In such cases either the ordinarily occurring form is taken as the type, and the series of occasional varieties is begun with β, as—

Sambucus nigra, L. ——, var. β. leaflets laciniated (Hooker & Arnott).

or, *Sambucus nigra*, L. —— β. *virescens* (fruit green). —— γ. *leucocarpa* (fruit white). —— δ. *laciniata* (leaflets laciniated). —— ε. *variegata* (leaves with white streaks), Koch.

Or if the species is variable and no one form is considered typical, the series begins with α, thus:—

Fedia dentata (Hooker & Arnott). —— α (*Valerianella Monsonii*, DC.). —— β (*Fedia mixta*, Vahl). —— γ (*Fedia eriocarpa*, Rœm. & Sch.).

The nomenclature of cultivated plants is fruitful in examples of named varieties in large numbers belonging to particular species, such as *Clarkia pulchella alba*, *C. pulchella rosea*, &c. &c.; but these names are often applied without scientific exactitude.

Hybrids are named according to certain rules when they occur frequently wild or, if obtained artificially, when they are propagated by cuttings, bulbs, &c. The names of the two parent species are combined, thus:—*Verbascum nigro-Lychnitis*, a hybrid between *V. nigrum* and *V. Lychnitis*. With regard to artificially produced hybrids, it is possible to indicate the parentage with more accuracy, and the name of the seeding plant stands before that which yields the pollen, as *Amaryllis vittato-reginæ*, the form produced when the ovules of *A. vittata* are fertilized by the pollen of *A.*

eginæ, and *vice versâ*. Where a plant is known to be of hybrid origin, it is a good plan to indicate the fact by prefixing × to the name.

The nomenclature of the groups above genera is of less importance than that of genera and species, and is dealt with more independently by individual writers. Artificial groups are generally named from the character on which they are founded, as in the case of the Linnean classes and orders. The same is the case with the artificial divisions which are used in most Natural Arrangements for conveniently subdividing large assemblages of Families or Orders, such as *Thalamifloræ* &c. of De Candolle, *Polypetalæ* &c. of Jussieu. But as the essence of the Natural Arrangement of plants lies in the combination of forms according to the majority and importance of points of likeness or general character, we are not necessarily restricted by any definite character in the selection of the name; and in regard to the Natural Orders, great diversity of principle has prevailed in the application of the names, and even considerable latitude in the form given to them. There exists, however, one rule applied in all Latin naming of what are termed Natural Orders: the word *plantæ* is *understood*, and an adjective name agreeing with this represents the group. In existing systems we find these adjective names founded sometimes on a prevalent character in the family, as (plantæ) Leguminosæ, Coniferæ, Umbelliferæ, &c.; sometimes on the names of typical genera, as Rosaceæ, Solanaceæ, Convolvulaceæ; sometimes on an existing general name derived from common language, as Graminaceæ and Palmaceæ. A difference of termination exists even in regard to the same word in different authors: thus, one author writes Cistineæ, another Cistaceæ, with the same meaning; while others use the word Aroideæ in preference to Araceæ, or Palmæ in preference to Palmaceæ.

Attempts have been made to reduce all these names to a system, and to preserve the same form of termination for groups of the same value. Thus it is proposed to make the names of all Orders end in *aceæ*, like Ranunculaceæ, Ericaceæ, &c., the only objection to which is the necessity of discarding many familiar and well-established names, and replacing them by strange ones, as Apiaceæ for Umbelliferæ, Fabaceæ for Leguminosæ, &c. "Classes" or "Alliances" again are made alike by using the terminal form *-ales*: as Glumales, instead of Glumaceæ or Glumiferæ, for the group composed of the Orders with a glumaceous perianth, &c.

A fixed rule does exist among all modern writers in the denomination of *suborders* or *tribes* into which Orders are divided; for these are founded on typical genera, the names of which are made to furnish adjectives by the substitution of *eæ* for the last vowel and whatever may follow it: for example, in the Order of the

Ranunculaceæ, we have the tribes *Anemoneæ* from *Anemone*, *Ranunculeæ* from *Ranunculus*, *Helleboreæ* from *Helleborus*, &c.; and in botanical works these names of tribes are commonly printed in *italics* like those of genera and species, while the names of families and all above them are printed in roman letters.

The names applied to the larger divisions of the Vegetable Kingdom in Natural Arrangements are generally made as characteristic as possible; but, as will be shown in the Section on Natural Arrangements, none of the single characters of such groups are absolute, and therefore no name founded on one character can be universally descriptive. Thus the name Monocotyledones is applied to a most natural group, in which are, however, included one or more orders, as the Orchidaceæ, in which the embryo has no cotyledons. And it may be said that to an advanced student it is far more beneficial to regard all names as abstract signs, used rather to indicate certain plants or groups of plants with which he is acquainted, than as expressive of the characters of the plants to which they are applied.

These observations on the nomenclature of the Orders and higher groups of plants are placed here for the sake of connexion with the remainder of the subject; but they will be better appreciated after acquaintance is made with the illustrations of them in succeeding Sections.

Sect. 3. Description of Plants.

It is the business of every botanist who distinguishes and names a new species of plant to furnish an exact statement of the characters by which it may be recognized by others.

The most complete fulfilment of this requisition is supplied in what is termed a *description* of a plant, in which is given a detailed account of the external form, the arrangement and relations of all its organs, according to a fixed plan and in a fixed language, furnished by the terminology made use of in Morphology.

In order to impress upon the mind of the student the principal points to be looked to in describing a plant, and thus to ensure completeness and accuracy of observation, we subjoin a list of the more salient characteristics which it is desirable to notice in writing a full description of a plant. Some of these are of much greater importance than others, inasmuch as they afford the means of grouping plants into genera and orders, not only physiologically but morphologically, &c., and furnish what are called *diagnostic characters*. From their great importance, much stress is deservedly laid on them; hence, after enumerating the principal "characters" necessary to be ascertained in drawing up a full description, we shall insert illustrations of the "schedules" introduced with so much success for teaching-purposes by the late Professor Henslow, and in which attention is drawn solely to those points of special importance.

It must also be borne in mind that the terms used are such as are in general use, and are to be taken in their conventional sense, and not as

necessarily expressing the exact truth: thus, as has already been explained under the head of Morphology, when we say that one organ is *inserted into* another, it would be more correct to say that the one emerged from the other; in the same way many cases of so-called *cohesion* and *adhesion* are shown, by the study of the progressive development of the flower, to be rather cases of arrested separation than of union of originally distinct organs.

In describing a plant fully, a commencement is made with the root, from which we proceed to the stem, leaves, inflorescence, flowers, and, finally, the ripe fruit and seeds.

In the case of the *root* the principal points to be looked to are:—first its *nature*, whether true or adventitious; then, in succession, its *form, direction, size*, degree and mode of *ramification, duration, consistence, surface, colour*, &c. Similar remarks apply to the *stem* and its modifications.

Leaves require first to be noted as to their *position*, radical, cauline, &c.; *insertion*, stalked or sessile; possession or deficiency of stipules; *arrangement*, alternate, opposite, &c.; *composition*, simple or compound; *direction, duration, texture, colour*, and *surface*. The *blade* of the *leaf* must then be described as to its *general form, outline, base, apex, margins, mode of venation, size* (especially in relation to the stalk, if present). The subdivisions of a compound leaf must be treated in the same manner as simple leaves. The *petiole* or leaf-stalk has to be noted as to its *form, surface, relative size*, &c. *Stipules*, as far as practicable, should be described in a similar manner to the leaves, as also should, *mutatis mutandis*, the *leaf-buds*. In their case, as also in the case of *flower-buds*, the mode of *vernation* or of *æstivation*, as the case may be, should be ascertained and recorded. As regards the *inflorescence*, the principal things to be considered are its *position, direction, relative size* as compared with the leaf, *nature* (definite or indefinite), *ramification, form, number of flowers, duration*, &c.

The *flower-stalks* follow the same rule as the leaf-stalks; but particular attention should be paid to the top of the flower-stalk (the *thalamus*) to see whether it be flat, convex, or concave. The *bracts* are described in the same manner as the leaves. In the case of the *calyx* and *corolla*, attention should be directed to their *construction* (cohesion), *relative position* (adhesion), *form, direction, colour, venation, surface, size*, absolute and relative, *duration, odour*, &c.

Individual *sepals* or *petals* should be described in the same way as the leaves.

Stamens should be described with reference to their *insertion* (adhesion), *cohesion* (free or united), *number, position, arrangement, size* (with reference to one another and to the other parts of the flower). *Filaments* present similar characters to those offered by the leaf-stalks, and are described accordingly. *Anthers* require attention as to their *form, mode of attachment* to the *filament, shape* and *number* of their *lobes*, their *mode of dehiscence, colour, surface*, the form and peculiarities of the *connective* and of any appendages that may be present. The *form, colour*, and distinctness or cohesion of the *pollen-grains* should, if possible, be stated. This is not always practicable unless recourse be had to the compound microscope, when other peculiarities, then visible, should be noted, as will be further explained in the section on Physiology.

After the stamens, the characteristics of the *disk*, if present, should be

noted, and then those of the *pistil* as follows—*number* of the constituent carpels, their *isolation* or *cohesion* and *arrangement*, their *adhesion* and *relative position, form, cavities, partitions*, and mode of *placentation*. The *styles* require to be noted with reference to their *position, number, size* (*relative* and *absolute*), *form, surface, colour*, &c. Similar remarks apply to the *stigma*. The *ovules* differ in their *position, mode of attachment, number, form*, &c. The *fruit* follows the same rules as the pistil; but, in addition, the *texture, mode of dehiscence*, and *number of seeds* must be noted.

Seeds are described much in the same way as ovules, taking care not to overlook any of the peculiarities presented by the *coverings* of the *seed* in the way of hairs, scales, arils, and the like: the interior of the seed also requires special attention, to see whether or not it be *albuminous* or *exalbuminous*; if the former, the nature and quantity of the *albumen* should be noted; and in any case, where possible, the *form, position, direction, size* of the *embryo* and its parts, the nature and number of the *cotyledons*, &c. should be accurately ascertained.

The student is recommended to take any plant he meets with, and endeavour to draw up a description of it with reference to the foregoing scheme. By comparing the description of one plant with that of another he will familiarize himself with the main points of difference between one plant or one organ and another, and will learn to apply the appropriate *term* to each modification.

The subjoined description of the common white Dead-Nettle (*Lamium album*) is given as an illustration of a tolerably complete description of the external peculiarities of a plant; it may serve as a model to the student in drawing up similar descriptions. It is, however, advisable that he do not attempt too much at once. A bad or careless description is almost worse than none at all; hence the beginner is recommended to make himself pretty thoroughly acquainted with the peculiarities of such organs as are most easily studied before passing on to organs such as ovules, &c., which require some considerable practice before their structure and characteristic features can be ascertained.

Lamium album.—A rather coarse hairy perennial, with a shortly creeping *stock*, from the joints of which, especially on the lower surface, proceed at intervals numerous slender, fibrous, brownish *roots*. *Stems* 1–2 feet high, herbaceous, decumbent or ascending, fistular, four-sided. *Leaves* exstipulate, opposite, stalked, the upper ones nearly sessile, hairy, membranous, ovate-acute or acuminate, cordate, coarsely and irregularly toothed, unicostate, arch-veined, 2–3 inches long, 1–2 inches broad. *Petiole* less than half the length of the blade, channelled on the upper surface, rounded beneath. *Flowers* pure white, sessile, in axillary cymose whorls (verticillasters) of 6–10 or more. *Calyx* campanulate, of 5 sepals, united below into a *tube* traversed by 10 ribs; *limb* divided above into five nearly equal, spreading, linear, ciliated segments, of which the uppermost stands slightly apart from the others. *Corolla* white, tubular, bilabiate, twice the length of the calyx; *tube* curved, ventricose, as long as or longer than the calyx, scabrous inside, with a ring of hairs near the base; upper lip erect, concave, notched, hairy on the outer surface; lower lip spreading, 3-lobed, the middle lobe broad and 2-lobed, the two lateral ones small and pointed. *Stamens* 4, didynamous, epipetalous: *filaments* downy, springing from the upper part of the tube of the corolla, partially concealed within the upper

ɔ. *Anthers* innate, 2-lobed; lobes superposed, oblong, blackish, introrse, ›hiscing longitudinally; *connective* covered with white hairs. *Pollen* ›llowish white. *Ovary* small, truncate, 4-lobed, 4-celled, encircled at ıe base by a pale green, cup-like disk. *Ovules* solitary in each cell, ana-'opal. *Style* single, basilar, thread-like, as long as the corolla, termi-ıting in a 2-lobed stigma; lobes of the stigma short, oblong, pointed. *'ruit* of four (or fewer by abortion), 1-celled, 1-seeded, indehiscent, blackish ıining lobes or achenes. *Seeds* solitary, erect, inverted, exalbuminous. *'mbryo* straight; *cotyledons* large, plano-convex; *radicle* short, inferior.

Such descriptions are now usually given in a modern language 'hen occurring in works descriptive of the plants of particular ountries and intended for general use, &c. In general systematic 'orks, or in isolated notices, published in periodicals or Transactions, ,ddressed more particularly to proficients, the Latin language is ısually preferred, as it is understood by botanists of all nations and s less vague in its application.

Detailed descriptions are commonly given only where new spe-ies are established, or when an uncertain nomenclature is to be nade clear and definite, in a monographic or a general systematic vork. The classification of plants into genera, families, &c., in the Natural System, renders the repetition of the peculiar marks of hese groups unnecessary in the characterization of the subordinate groups or forms. For this reason, *characters* and *diagnoses* com-nonly replace the complete descriptions of species in ordinary lescriptive botanical works, since, as the character of the genus ncludes those peculiarities of the floral organs which are common to all its species, and which constitute the bases of the genus, it is only requisite to connect with each species the character by which that species is distinguished from others.

The following condensed description of the white Dead-Nettle, from Bentham's 'Handbook of the British Flora,' will show how, when the characters of the order and genus are known, a faithful portrait of the species, and one comprising the most conspicuous features only, may be drawn up:—"A rather coarse hairy perennial, with a shortly creeping stock, and decumbent or ascending branching stems, sel lom above a foot high. Leaves stalked, coarsely crenate. Flowers pure white, in close axillary whorls of 6–10 or more. Calyx-teeth fine, long, and spreading. Tube of the corolla curved upwards, and longer than the calyx, with an oblique contraction near the base, corresponding with a ring of hairs inside; the upper lip long and arched; the lateral lobes of the lower one slightly prominent, with a long fine tooth." Then follows an account of the *station* in which the plant is found, and of its geographical distribution throughout this country and the continent.

Value of Characters.—Having gained a general idea of what points are to be looked to in drawing up a description of a plant, and having acquired a familiarity with the meaning and application of terms, it is particularly desirable that the student should be able to form an estimate of the *relative value* and *importance* of characters for practical purposes: for

instance, those characters which serve to identify and distinguish large groups of plants are of more consequence than such peculiarities as pertain merely to small groups or to individual plants. With a view to fix the attention on the more important or cardinal characters, those which are of most use in drawing up a *diagnosis* of a plant or of a group of plants, a form of schedule is given; and the pupil is recommended to make similar ones for himself, and by their aid to draw up an account of the more important characters of any flowers he meets with, checking them and comparing them with the descriptions given in books, or with the instructions of his tutor. These schedules should be kept for comparison with others relating to other plants; and by this method a practical insight into plant-construction, and the relationships of one plant to another, may be more speedily and thoroughly obtained than by any other means. The schedules here inserted by way of illustration are filled up from a Common Buttercup (*Ranunculus*) and from a Dead-Nettle (*Lamium*). The characters therein given are sufficient to enable the student to determine the *orders* to which the plants belong, which is the first and most important consideration; but they are not sufficient to indicate the *genus*, still less the particular species. To discriminate these minor groups, recourse must be had to the other peculiarities presented by the plants in question, as before detailed.

Calyx	polysepalous						regular.
Sepals	5	distinct	verticillate	hypogynous			
Corolla	polypetalous						regular.
Petals	5	distinct	verticillate	hypogynous			
Stamens	polyandrous						
Filaments	indefinite	distinct	spiral	hypogynous			regular.
Anthers	2-lobed	distinct					
Pistil	polycarpous						
Carpels	indefinite	distinct, apocarpous.	spiral				regular.

Lamium (Dead-Nettle).

Organ.	Number.	Isolation.	Arrangement.	Insertion or Emergence.	Cohesion.	Adhesion.	Form.
Calyx					gamosepalous		irregular, bilabiate.
Sepals	5		verticillate	hypogynous			
Corolla					gamopetalous		irregular, bilabiate.
Petals	5		verticillate	hypogynous			
Stamens.							
Filaments	4	distinct	verticillate	perigynous		epipetalous	irregular, didynamous.
Anthers	2-lobed						
Pistil.							
Carpels	2		opposite		syncarpous		irregular.
Ovary	4-lobed						
Styles	2				confluent		basilar.
Stigmas	2	distinct					

Generic Character.—The *generic character* is perhaps the most important element in Systematic Botany. It should contain a short description of the peculiarities of the group, so as at once to characterize this as it exists in itself, and to furnish the means by which it may be distinguished from all other genera belonging to the same division of the Vegetable Kingdom. The following example of the character of the genus *Campanula*, Linn., as given in Endlicher's 'Genera Plantarum,' will illustrate this:—

"*Campanula*, Linn.—*Calyx* with an ovoid or subspherical tube adherent to the ovary, the limb superior, five-toothed; the teeth either flat at their margins or decurrent into lobes overlying the sinuses. *Corolla* inserted at the summit of the tube of the calyx, more or less campanulate, five-lobed or five-toothed at the apex. *Stamens* five, inserted with the corolla; filaments broadly membranaceous at the base, and, with the anthers, free. *Ovary* inferior, three- or five-celled; cells superposed to the lobes of the calyx. *Ovules* numerous, on placentas projecting from the central angles of the cell, anatropous. *Style* covered with quickly deciduous hairs; *stigmas* 3–5, filiform. *Capsule* ovate or turbinate, 3–5-celled; cells bursting near the top or bottom by a parietal valve turning upward. *Seeds* numerous, mostly ovate, flattened, more rarely ovoid and very small. *Embryo* orthotropous, in the axis of fleshy albumen; *cotyledons* very short; *radicle* next the hilum, centripetal.

"Perennial or annual herbs, sometimes low and tufted, sometimes erect, tall, many-flowered, diffused through all the temperate and cool regions of the northern hemisphere, forming a great ornament to meadows and groves; radical leaves very often larger and more obtuse, with longer stalks; stem-leaves alternate, varying; flowers mostly stalked, racemose, rarely spiked or in clusters, very often rather large, blue, or sometimes white in the same species."

The first paragraph here contains the *essential character* of the genus: the second paragraph is a description of the general characters of the species belonging to it, which is usually appended to such complete generic characters.

It will be observed that this generic character not only enables us to distinguish plants belonging to this group, but describes the genus so fully that we become acquainted with all its important peculiarities, while, being drawn up irrespectively of any Order, alliance, or class, it is equally available as material for any Natural or Artificial classification of Flowering plants founded on the floral organs, since it contains the information requisite for ascertaining its relations.

Diagnosis.—The *diagnosis* of a genus is more limited in its nature and purpose. It is used, when genera are described under fixed systematic heads, simply for distinctive purposes; and it is therefore confined to denoting what is absolutely necessary for this purpose. Thus, in Babington's 'Manual of British Botany,' the genus *Campanula* occurs under the head of the Order Campanulaceæ, the character of which includes much of what is given in the generic

character of *Campanula*, above cited; so that it suffices for the distinction of *Campanula* from its allied genera to give the following brief abstract, or *diagnosis* :—

"*Campanula* :—*Calyx* 5-parted. *Cor.* mostly bell-shaped, *with 5 broad* and shallow segments. *Anthers* free; *filaments* dilated at the base. *Stigma* 3–5-fid. *Capsule* not elongated, 3–5-celled, opening by lateral pores outside the segments of the calyx."

It is seen at once that this *diagnosis* fails to furnish the complete notion of the genus which is obtained from the *descriptive character*, and that it does not suffice to indicate the position of the genus, either in a Natural or Artificial classification. On the other hand, for its own especial purpose (that is, of indicating the distinctions between allied genera), it may be even still more reduced, as is often done in works describing the plants of a limited district, where only a few genera occur in the natural order; for example, we might give diagnoses of the British genera of Campanulaceæ in this way—

A. Corolla rotate, segments linear; anthers cohering at the base. 1. *Jasione.*
   Corolla rotate, with linear segments; anthers free. 2. *Phyteuma.*

B. Corolla mostly bell-shaped, with broad and shallow segments; anthers free.
   Capsule not elongated, opening by lateral pores outside the segments of the calyx.................... 3. *Campanula.*
   Capsule linear-oblong, prismatic, opening by lateral pores between the segments of the calyx .... 4. *Specularia.*
   Capsule half-superior, opening by 3–5 valves within the segments of the calyx .... 5. *Wahlenbergia.*

Specific Character.—The *specific character* of a plant should mention all the constant distinctive peculiarities of a species. On the one hand, it should exclude the generic characters which ally it to other species of the same genus; on the other, it should exclude the inconstant characters which distinguish its own varieties. But the character of its ordinary varieties, if such exist, may be given in a supplementary paragraph, like that appended to the full generic character. The distinctive characters of species are usually found in the organs of vegetation, as the root, stem, leaves, bracts, and inflorescence, or in the habit or duration of the plant. The floral organs mostly only give specific characters in their less important peculiarities—as in the shape and relative magnitude of the petals, the external characters of the fruits and seeds, &c.—the more remarkable peculiarities being of generic value. The supplementary notices appended to the strict character of the species generally relate to the ordinary dimensions of the plant, the colour, taste, smell, &c. of its organs; these are the marks by which the *varieties* are usually characterized, as will be seen by referring to any catalogue of varieties of the ordinary cultivated vegetables.

The specific character will necessarily vary in length according to the richness of a genus in species, some containing many hundreds, while others comprise but a single one. When the genus contains but a single species, as the Hop (*Humulus Lupulus*), the generic character alone suffices for distinguishing it; but a specific character is even then given with advantage, indicating points which are not included in the strict generic character. Where a large number of species exist, the genus is generally broken up into artificial sections, characterized by some mark occurring regularly in a certain number, which are thus placed under one head: this saves the necessity of repeating that character for each species. It is also common in modern works to combine a diagnosis with the specific character, by marking in italics the especial distinctive marks of each species occurring in a particular group.

The following examples will make this more clear:—

Of *Syringa*, L., only six species are described in De Candolle's 'Prodromus,' being all that were known in 1844. The specific character of the common Lilac, *Syringa vulgaris*, could thus be given in a few words:—

"*S. vulgaris*, L. Leaves cordate or ovato-cordate, quite smooth and of even colour; limb of the corolla subconcave."

Four varieties are characterized, chiefly distinguished by the colours of the blossoms.

Turning to the genus *Campanula* in the same work, we find no less than 182 species. Being a very natural genus, the species are kept together under one generic name, but, for convenience, they are arranged in sections and subsections. Thus fifty-eight of them are characterized by the presence of appendages on the sinuses of the calyx, such as we find in the garden Canterbury Bell (*Campanula Medium*), while the remainder are without these. The second section, of 124 species (among which are included all our native kinds), is further divided into subsections, characterized principally by the peculiarities of the *capsule*, and these, again, into groups according to the kind of *inflorescence*, &c.; so that when we come to the specific character itself none of these points have to be repeated, and the definitions are restricted within very narrow limits, as for instance:—

"*C. rotundifolia*, L. Radical leaves stalked, cordate, rounded, crenato-dentate; stem-leaves linear or lanceolate; teeth of the calyx awl-shaped, erect, one-third the length of the bell-shaped corolla."

In a work devoted to a limited flora, as that of Britain, where there exist only eight species of *Campanula*, we may adopt the sectional divisions, and limit the specific character as above, or give a longer character, including the marks of the sections; the latter plan is the better, where space is not an object, since it makes the character itself more instructive. Thus, in the 'British Flora,' we find—

"*C. rotundifolia*, L. Glabrous; root-leaves subrotundo-cordate, crenate (very soon withering), lower cauline ones lanceolate, upper linear entire; flowers solitary or racemose, drooping; calyx-segments subulate; capsule drooping, with the clefts at the base."

In Babington's 'Manual,' on the contrary, where the subsections founded on the capsule are adopted, this mark is omitted in the essential character:—

"*C. rotundifolia*, L. *Radical leaves cordate or reniform*, shorter than their stalks; *stem-leaves linear*, the lower ones lanceolate; *flowers one or*

more, racemose; corolla turbinate-campanulate.—Stem 6-12 inches high. Radical leaves soon vanishing; corolla blue; calyx-segments linear-subulate."

This example further illustrates the method of giving a *diagnosis* at the same time, by *italicizing* the characters by which the species is distinguished from its nearest allies; it also shows the manner in which explanatory or descriptive notices are added in a supplementary paragraph to the essential specific character.

Lastly, if we have to deal with a limited number of species, such as the British Bell-flowers, to which we have just referred, we may, for simple purposes of distinction, construct a diagnostic table, like that above given for the genera of Campanulaceæ.

- Flowers sessile, in terminal or axillary clusters; capsule sessile, erect, with the pores at the base . . *C. glomerata.*
- Flowers in racemes or panicles; capsule stalked.
  - Capsule nodding, with the pores at the base.
    - Flowers in a unilateral raceme, segments of calyx ultimately reflexed . . . . *C. rapunculoides.*
    - Flowers racemose, segments of calyx always erect.
      - Peduncles 1-flowered . . . . *C. latifolia.*
      - Peduncles 2–3-flowered . . . . *C. Trachelium.*
    - Flowers on long slender stalks, solitary, or in a lax few-flowered corymbose raceme . . *C. rotundifolia.*
  - Capsule erect, with the pores just below the segments of the calyx.
    - Segments of the calyx entire.
      - Segments of the calyx lanceolate; raceme few-flowered, or flower solitary . . *C. persicifolia.*
      - Segments of the calyx awl-shaped; flowers in an erect racemose panicle . . . . *C. Rapunculus.*
    - Segments of the calyx toothed at the base; flowers panicled, erect, on long stalks . *C. patula.*

A few of the general rules observed in writing descriptions of plants may be mentioned here, as explanatory of certain technicalities which will be met with in systematic works.

The generic name is always commenced with a capital letter, while that of the species is usually written small: but we find in most books a capital letter to the specific name, 1, where this name is the appellation of another existing or suppressed genus used adjectively, as *Agrimonia Eupatorium*, *Mentha Pulegium*, &c.; 2, where the specific name is formed from a proper name, either as the genitive case of a substantive or in the adjective form, as in *Scirpus Savii* and *Carex Davalliana.* Specific names derived from countries are now usually written small, as *Silene anglica.*

When a generic character is written in Latin, the descriptions of the organs are all put in the nominative case; in a specific character they are put in the ablative.

When describing a species, it is usual to subjoin its habitation (*Habitat*)—that is, the nature of the places in which it is usually found, such as "Woods," "Dry hilly places," "Rivers," &c. In general systematic works the native country or province is stated; in works relating to limited districts, special *localities* are given for rare plants.

The following marks and abbreviations are commonly in use to indicate certain other points:—

(1) or A = an annual plant.	♂, a male flower.
or B = a biennial.	♀, a female flower.
or P = a perennial.	⚥, an hermaphrodite flower.
Sh = a shrub.	♂ ♀, a monœcious plant.
T = a tree.	♂–♀, a diœcious plant.

The time of flowering is indicated by numbers, referring to the months, as 6–8 or vi–viii = June to August, &c. (See also p. 103.)

Many other signs are met with in Systematic works, but they are very often used in different senses by different authors, so that no general explanation of them can be given; moreover the sense in which they are used is generally explained by the author.

CHAPTER II.

SYSTEMS OF CLASSIFICATION.

Sect. 1. Artificial Classification of Plants.

An arrangement of all known species of plants in a series of classes, constituted upon certain fixed principles, forms what is termed a System of Vegetables.

The classification of plants by generalization, the Synthetic or Natural Method, is adopted in all cases in forming the groups of the lowest rank, namely *Genera*. These are established by the combination of a number of allied species under one name, on account of their affinities; and, as we have already mentioned, the same genera are used in all Classifications.

From this point Systems diverge. The *Natural Method* is pursued further on the same principles of generalization, where the object is to systematize acquired knowledge, mark the agreements and determine if possible the lineage of plants. Where, on

the other hand, it is chiefly desired to mark out the differences of plants, in order simply to their easy recognition, *Artificial Methods* are resorted to, which are carried out by a principle of *analysis*, whereby the whole mass of known forms is taken and gradually parcelled out into Classes, Orders, &c., according to their agreement or difference in certain fixed characters.

Most of the older systems were more or less Artificial, the earliest commencing with the division of plants into Trees, Shrubs, and Herbs, Land-plants and Water-plants, and the like. As advances were made, organs of more and more importance were chosen to furnish characters; and we find plants subsequently classed by their *corollas*, by their *fruits*, &c.; but in none of the systems proposed before the time of Linnæus do we find one given principle carried out through the whole.

The Linnæan System.—When Linnæus entered upon his labours, there lay before him a mass of information in a very unmanageable condition. His reforming genius introduced order, in the first instance, by the substitution of short fixed names for species, on the binomial plan, by the definition and secure establishment of imperfectly characterized genera and species, and then advanced to the necessary task of arranging the genera so as to render them recognizable. The artificial methods founded on the floral envelopes &c. had proved insufficient; and therefore he turned to the *essential organs* of flowers, the physiological importance of which he himself contributed greatly to establish. The selection of these organs resulted in the formation of an Artificial System in which a fixed principle is regularly carried out, and which, from the physiological importance of the characters employed, approaches in certain of its coordinations to a natural arrangement.

Species and *Genera* form the foundation of all Systems. The object of the Linnæan System was to arrange genera in groups characterized by simple striking marks, so that the existing description of a given plant might be readily found, or the description of a new plant might be placed where it would be easily referred to. Such marks Linnæus obtained in the *essential* or *sexual organs* of plants (in flowers, the *stamens* and *pistils*), whence his System is sometimes called the Sexual System. The highest or most general groups, which he called *Classes*, are founded on the conditions of the *stamens*. These Classes are subdivided into *Orders*, founded either on the conditions of the *pistils* or upon *secondary characters of the stamens*. The orders include the *Genera* (in large Orders grouped into sections according to various artificial characters). The Linnæan *Classes* are twenty-four in number, of which the first twenty-three include all Flowering Plants: the

twenty-fourth, Cryptogamia, including all Flowerless Plants, was a *chaos* when first established, and its subdivisions were not then definable by single characters. As the Linnæan system is no longer in use, further mention of it is not needed.

Sect. 2. Natural Classification of Plants.

In this method of classifying we pursue the same path by which we arrived at the genera, and combine these into more general groups, not according to arbitrarily chosen or isolated characters, but according to their natural affinities—that is, the agreement in their total organization, and consequently their presumed degree of kinship. Genera are thus gathered together into *Families* or *Orders*, these into *Cohorts* and *Classes*, and finally the entire Vegetable Kingdom becomes marshalled into a few *Provinces* or *Subkingdoms*.

It is evident from this, that a Natural System founded on a perfect knowledge of all existing plants would present to us a kind of abstract *picture of the Vegetable Kingdom, in which all its essential characters would* be represented in their real proportions, places, and connexion. Not only, however, are we far from being acquainted with all existing plants (not to mention the numerous kinds now extinct), but the essential peculiarities of a vast number of the known plants have been as yet but imperfectly studied. Hence we have at present various plans for the Natural Arrangement of plants, presenting peculiarities dependent upon the amount of knowledge, or the peculiar views, of their respective authors; which plans or Systems must be regarded as so many rough draughts or sketches, to serve as material for the elaboration of the true and complete Natural System. As the principles of classification are fully recognized, and as the amount of plants thoroughly known is already very large, there is a close agreement in the general features of the different "Natural Systems," and especially in the manner in which the Orders of plants are defined. The chief diversities of opinion arise out of the different estimations of affinities and differences of the families.

Value of Characters.—To characterize the Natural Method more distinctly, it must be added that especial attention is paid to the relative importance of the characters presented by each plant, a determinate scale being formed, in which the organs are ranked according to their "congenital" or "acquired" origin, their physiological importance, the complexity of their construction, and their comparative invariability. Congenital characters are common to the largest number, and are the most constant, hence the most important.

Thus, while species of the same genus, distinguished generally by the external characters of their vegetative organs, are combined by likeness in their flowers, genera (in which difference of the floral envelopes, or of the external character of the fruit, or some such character exists) are

combined into an Order on account of the agreement in the structure of the ovary and its relations to the floral envelopes. The characters of seeds, and more particularly of the embryos, give a still higher divisional character. These characters of successively higher groups are marked in organs of progressively higher physiological and morphological importance, affinities between such organs being proportionately more valuable. But they possess this value not merely on their own account; for if that were the case, the method would be still to a great extent artificial: they indicate the coexistence of proportionate agreement in the total organization, which renders them exponents not merely of the affinities of the plants in respect to the particular structure to which they belong, but of all their affinities, and of the rank which a given plant holds in the Vegetable Kingdom. As a general rule, it is found that the agreement of the total organization of plants is generally proportionate to the physiological value of any given organs in which they agree; or, in other words, agreement in the structure of any given organ indicates general agreement in all the organs of less importance than itself. The agreement here referred to is of course a general structural agreement, a relation to a common type—not a resemblance excluding the multifold minor diversities which present themselves within the limits of almost every type.

Practically, moreover, we have another principle to keep in view, which indeed, while it affords as it were the verification of the inductions of the above principle, is our sole guide in dealing with the subdivisions of the more comprehensive types. This is the rule that the closest affinities are marked by the agreement in the majority of characters of *equal* importance; or if the characters, as is more commonly the case, are of unequal importance, the principle of decision by the majority is carried out by ascertaining the proportionate values of the organs in which agreements and differences exist, and striking a balance as with equal factors.

Many of the older botanists had attempted to construct a Natural System; and Linnæus left a sketch or fragment of one, in the form of a list of names of families without definitions, regarding its realization as the ultimate aim of Botany. Many of the families in these older Systems are grounded almost exclusively on "habit," or general external character. The two Jussieus, Bernard and Antoine-Laurent, have the merit of the discovery of the only principles upon which a really Natural System can be founded. And so accurately did A.-L. de Jussieu carry out these principles in his arrangement of the then existing genera, that the families which he established are still almost all received into our present Systems, where some of them are indeed broken up into smaller groups, but where the greatest increase in the number of families arises from subsequent discoveries.

The characters of the natural Families established in this way will be found to be far less exact and definite than those of the Linnæan classes and orders, and by no means so rigid even as those of natural genera. The character of a family is founded on the *totality* of its essential characters, and includes the essential characters of agreement of all its genera. The genera contained in most of the families exhibit a considerable range of differences;

allowance must be made for these; and this gives a laxity to the family character which is puzzling to the beginner. For example, the family Ranunculaceæ is very natural; but we find in its character a certain range of difference allowed for in the sepals, petals, pistils, and fruit; the insertion of all these, however, and that of the stamens, is fixed, and so is the character of the seed. Similar conditions occur in most other families. The decision as to what family a genus is to be referred to is made according to the principle of majorities: whichever it agrees with in *most* of its characters (say, even three out of five), to that family it belongs. Great difficulty, however, exists in certain cases from a vast series of genera running into one another by almost imperceptible gradations, and this in different directions. A considerable number of these agreeing closely are associated into a family; another similar group forms another family, and so on; and then, in the course of time, sundry intermediate genera present themselves, which connect the established families, and which it is difficult to place by the usual choice in either one or the other, the characters being balanced. Thus the Natural family Loganiaceæ is connected by "aberrant" genera with Rubiaceæ, Gentianaceæ, Scrophulariaceæ, and other families which are truly natural, but which in this way come to be separated by somewhat indefinite boundary-lines. The fact is, that the Vegetable Kingdom is a whole, the families having seldom a distinct isolated existence, except in the minds of botanists. It may be presumed that they are all variations from one or a few original stocks, and thus have numerous intermediate or connecting links; and we must regard them as analogous to countries on the globe, which are parcelled out under distinct names, but most often adjoin and run into one another, being only separated by an arbitrary boundary-line. Some, indeed, lie off from the rest, like islands, the intervening links being extinct; but these are the exceptions. Such exceptions are found among the families which were established by the older botanists, in which the essential agreements are accompanied by a striking character of external habit, as in the Grasses, the Umbelliferæ, the Compositæ, the Leguminosæ, the Coniferæ, the Palms, &c. Such remarkable peculiarities as these families possess mostly prevent them being broken up into smaller groups, as has occurred to many of the earlier orders of large extent; and most botanists prefer to distribute these genera into *suborders* rather than discard the characteristic general name. Examples of these are found especially in the Leguminosæ, Rosaceæ, and Compositæ.

The Families or Orders are for the most part the same, in all essential respects, in all existing "Natural Systems." A considerable diversity presents itself in the modes in which different authors have grouped these into *Classes* or *Alliances*. These, however, are still Natural groups, as are also those of still higher generality indicated in the chapter on General Morphology. But all writers on Systematic Botany have found it requisite to group the Orders or Classes of Flowering Plants into sections of somewhat less generality than Dicotyledons and Monocotyledons, as these respectively include series of families so extensive as to be inconvenient in practice if left undivided. The members of these series, however, are so intimately connected together by their natural

affinities, that it has been found indispensable to have recourse to certain arbitrary or artificial characters for the foundation of the sections—characters derived chiefly from the conditions of the petals and stamens. The nature of these Sections will be best understood from the examples which follow.

The Jussieuan System.—Jussieu established his primary divisions of the Vegetable Kingdom on characters which, although not unexceptionable, define really natural groups, which are found under different titles in all Natural Systems. The characters were the absence or presence of the embryo, and its structure when present, in the seed. On these characters stood the three divisions *Acotyledons* (plants without an embryo), *Monocotyledons*, and *Dicotyledons*. The first of these names is bad, as founded upon a *negative* character; but the plants which it included were imperfectly understood in the time of Jussieu; the Acotyledons correspond to the Cryptogamia of Linnæus, which are now by more complete analysis distributed into two sections, divided by even more important characters than the Monocotyledons and Dicotyledons. The other two divisions are still retained, with very slight modifications, in all Systems, but are subordinated under divisions founded on more important characters.

The following Table exhibits Jussieu's arrangement:—

				Class
Acotyledons				I.
Monocotyledons		Stamens hypogynous		II.
		„ perigynous		III.
		„ epigynous		IV.
Dicotyledons	Apetalous	Stamens epigynous		V.
		„ perigynous		VI.
		„ hypogynous		VII.
	Monopetalous	Corolla hypogynous		VIII.
		„ perigynous		IX.
		„ epigynous	Anthers coherent	X.
			Anthers distinct	XI.
	Polypetalous	Stamens epigynous		XII.
		„ hypogynous		XIII.
		„ perigynous		XIV.
	Diclinous, irregular			XV.

The three primary divisions here are natural; the Classes must be regarded as artificial; the Families, however, into which the latter are divided, are natural groups, and to a great extent are retained in more modern systems. The families of Jussieu were more carefully defined, corrected, and extended by Robert Brown, whose researches contributed most essentially to the establishment of the Natural System; but he did not attempt to establish any general plan for their coordination in Classes.

De Candolle's System.—Aug. Pyrame De Candolle endeavoured to classify the Vegetable Kingdom on principles more in harmony with the knowledge of the structure of plants accumulated since the promulgation of Jussieu's System. De Candolle's System has become very generally used, on account of its having been adopted in the great Descriptive work which he commenced, the 'Prodromus Systematis Naturalis Regni Vegetabilis,' a description of all known species of plants. His subdivisions of the Exogens (or more properly Dicotyledons) are retained in many works. They are artificial, like the "Classes" of Jussieu, but are, like them, convenient for the distribution of the families into groups of manageable dimensions. They are four in number, and founded on characters of the floral envelopes, viz.:—1. THALAMIFLORÆ, in which the petals are distinct and (like the stamens) inserted on the receptacle (hypogynous); 2. CALYCIFLORÆ, with the petals distinct or coherent and (with the stamens) inserted on the calyx (perigynous); 3. COROLLIFLORÆ, with the petals coherent, and inserted on the receptacle (the stamens being inserted on the corolla); and, 4. MONOCHLAMYDEÆ, or plants with a perianth or a single circle of envelopes.

In De Candolle's enumeration of the families, which had greatly increased in number from Jussieu's list, the reverse order of sequence is followed, the higher plants standing first. As regards this point, however, it is a misconception to place the *Thalamifloræ* first among the Dicotyledons, since they are manifestly inferior to the *Calycifloræ*, and even to the *Corollifloræ*.

During the last forty years a great many attempts have been made to distribute the Orders more satisfactorily into Classes and primary Divisions. Endlicher, Bartling, Meisner, Brongniart, Lindley, and many other authors have published Systems of their own.

Endlicher's System.—That of Endlicher has been extensively used, and, moreover, is the basis of arrangement in his great 'Genera Plantarum.'

Region 1. **Thallophyta.** Sect. I. PROTOPHYTA; II. HYSTEROPHYTA.

Region 2. **Cormophyta.**

Sect. III. ACROBRYA. *Cohort* 1. Acrobrya anophyta; 2. Acrobrya protophyta; 3. Acrobrya hysterophyta.

Sect. IV. AMPHIBRYA. V. ACRAMPHIBRYA. *Cohort* 1. Gymnospermeæ; 2. Apetalæ; 3. Gamopetalæ; 4. Dialypetalæ.

The cohorts are subdivided into classes, and these again into orders.

Brongniart's System.—The arrangement of Brongniart is much followed in France. Its general character may be understood from the following table:—

Division I. **Cryptogamæ.** Branch 1. AMPHIGENÆ (Thallogens); Branch 2. ACROGENÆ.

Division II. **Phanerogamiæ.**

Branch 3. MONOCOTYLEDONES. Series 1. Albuminosæ; 2. Exalbuminosæ.

Branch 4. DICOTYLEDONES.

Subbranch 1. *Angiospermæ.* Series 1. Gamopetalæ: § i. Perigynæ; § ii. Hypogynæ. Series 2. Dialypetalæ: § i. Hypogynæ; § ii. Perigynæ.

Subbranch 2. *Gymnospermæ.*

Lindley's System is the one proposed by its distinguished author in his 'Vegetable Kingdom.' Although the system itself was never generally adopted, the book itself is an admirable encyclopædia on all points relating to Systematic Botany and the uses of plants up to the date of publication. Lindley's main groups were:—I. THALLOGENS; II. ACROGENS; III. RHIZOGENS; IV. ENDOGENS; V. DICTYOGENS; VI. GYMNOGENS; VII. EXOGENS; the latter being subdivided into Diclinous, Hypogynous, Perigynous, and Epigynous subclasses. The subclasses were again divided into alliances, and these into orders. The special peculiarity of this system is the formation of a group for certain root-parasites, destitute of true leaves; and of Dictyogens—a class of plants with the netted venation of Exogens and the ternary flowers of Endogens.

Bentham and Hooker's System.—Since the publication of the 'Vegetable Kingdom' a very important work on Systematic Botany has been commenced by Mr. Bentham and Sir Joseph Hooker, entitled 'Genera Plantarum.' This work, so far as at present published, comprises a description, in Latin, of all the known genera of Polypetalous and Gamopetalous Exogens, together with analytical tables admitting of the ready determination of any particular genus, notes of aberrant or exceptional forms, &c. Their scheme is more fully explained in the English translation of Le Maout and Decaisne's 'General System of Botany,' edited by Sir Joseph Hooker. Its main features are given in the following table. The arrangement of the Monocotyledons, however, is taken from Mr. Bentham's paper on the classification of Monocotyledons, in the 'Journal of the Linnean Society' for November 1876.

Subkingdom I. **PHANEROGAMIA.**

Class I. **Dicotyledones.** Subclass I. ANGIOSPERMEÆ. Division 1. *Polypetalæ.* Series 1. Thalamifloræ; 2. Discifloræ; 3. Calycifloræ.—Division II. *Monopetalæ.* Series 1. Epigynæ; 2. Hypogynæ v. Perigynæ.—Division III. *Apetalæ.* Series 1. Hypogynæ; 2. Epigynæ v. Perigynæ.—Subclass II. GYMNOSPERMEÆ.

Class II. **Monocotyledones.** Series 1. Epigynæ; 2. Coronariæ; 3. Nudifloræ; 4. Glumales.

Subkingdom II. **CRYPTOGAMIA.**

Class III. **Acrogens.**

Class IV. **Thallogens.**

Subordinate to the "series" are "cohorts," or groups of orders of equal value, though with different limitations, to the "alliances" in Lindley's 'System.' The only point which requires explanation here is the series *Disciflorœ*, which includes those polypetalous hypogynous orders in which there is a conspicuous hypogynous disk or series of glands, into or between which the stamens are inserted.

Braun's System.—In Germany the classification of A. Braun is now much followed. The following are his main groups of Phanegams as modified by Hanstein, Sachs, and others:—

DICOTYLEDONES.

Julifloræ.	**Monochlamydeæ.**	**Aphanocyclæ.**	**Tetracyclæ.**	**Perigynæ.**
Piperineæ.	Serpentarieæ.	Hydropeltidineæ.	*a. Gamopetalæ.*	Calycifloræ.
Urticineæ.	Rhizantheæ.	Polycarpæ.	Anisocarpæ.	Corollifloræ.
Amentiferæ.		Cruciﬂoræ.	Isocarpæ.	
			β. Eleutheropetalæ.	
			Eucyclæ.	
			Centrospermæ.	
			Discophoræ.	

Julifloræ correspond nearly to Amentales, and are characterized by spicate or amentaceous inflorescence, diclinous flowers, and mono- or achlamydeous flowers. Monochlamydeæ have a well-marked perianth of one row; Aphanocyclæ have calyx and corolla, the parts of the flower (except in some cases the carpels) being arranged in spiral cycles. In Tetracyclæ the parts of the flower are in whorls. This group comprises

the Thalamifloral, Calycifloral, and Corollifloral divisions of De Candolle. Perigynæ: perianth tubular below, bearing the stamens, and free from or adherent to the carpels. In this group the Calycifloræ have a single perianth, the Corollifloræ a calyx and corolla.

Classification of Cryptogams.—This is in a transitional state. The following is the latest arrangement, adopted by Sachs. It will be seen that the orders are arranged in two parallel series, according to the presence or absence of chlorophyll.

Group I. **Thallophyta.**

Class 1. Protophyta.

With chlorophyll.	Without chlorophyll.
Cyanophyceæ.	*Schizomycetes.*
Chroococcaceæ.	Sphærobacteria.
Oscillatorieæ.	Microbacteria.
Scytonemeæ.	Desmobacteria.
Nostocaceæ.	Spirobacteria.
Rivulariaceæ.	
Palmellaceæ.	——
Eugleneæ.	*Saccharomyces.*

Class 2. Zygosporeæ.

A. *Conjugating cells motile.*

Volvocineæ.	*Myxomycetes.*
[*Hydrodictyeæ.*]	
——	
Confervaceæ.	
Ulvaceæ.	

B. *Conjugating cells stationary.*

Conjugatæ.	*Zygomycetes.*
Desmidieæ.	Mucorini.
Diatomaceæ.	Piptocephalidæ.
Mesocarpeæ.	
Zygnemeæ.	

Class 3. Oosporeæ.

Sphæroplea.

Cœloblastæ.

Vaucheria .... { Saprolegnieæ. Peronosporeæ.

Œdogonieæ.

Fucaceæ.

[*Phæosporeæ.*]

Class 4. Carposporeæ.

With chlorophyll.

Coleochætæ.

Florideæ.
- Nemalieæ.
- Ceramieæ.
- Dudresnaya.

Characeæ.

Without chlorophyll.

Ascomycetes.
- Gymnoascus.
- Discomycetes.
- Erysipheæ.
- Tuberaceæ.
- Pyrenomycetes.
- Lichenes?

Æcidiomycetes.

Basidiomycetes.
- Exobasidium.
- Tremellini.
- Hymenomycetes.
- Gasteromycetes.

Group II. **Cormophyta.**

Series I. BRYOPHYTA.
- Class 1. Musci.
- Class 2. Hepaticæ.

Series II. PTERIDOPHYTA.
- Class 1. Filicales.
  - i. *Stipulatæ.*
    - Ophioglosseæ.
    - Marattiaceæ.
  - ii. *Filices.*
  - iii. *Rhizocarpeæ.*
- Class 2. Equisetaceæ.
- Class 3. Dichotomæ.
  - i. *Lycopodiaceæ.*
    - Lycopodieæ.
    - Psiloteæ.
    - Phylloglosseæ.
  - ii. *Ligulatæ.*
    - Selaginelleæ.
    - Isoeteæ.

Caruel's System.—Quite recently an arrangement has been proposed by Professor Caruel, based on the circumstance that there are in the same individual plants sexual forms or stages, male or female as the case may be, and an asexual or neutral form; thus in Phanerogams the asexual form is the embryo developing indefinitely and becoming ultimately an adult plant, which latter produces a male form, the pollen, and a female form, the ovule, which becomes a seed with definite evolution, containing "oospheres" or germinal vesicles in a closed "oogonium" or embryo-sac. The following are the outlines of the scheme, which we give in this place, though

it cannot be understood by the pupil until after he has made himself acquainted with the morphology and physiology of Cryptogams and Phanerogams and the details of the reproductive process in the several orders.

Caruel's primary groups are:—

I. PHANEROGAMÆ.—Plants trimorphic, one form neutral, producing agamically two sexual forms, male and female respectively; neutral form originating from a fertilized oosphere and developing into a pro-embryo, like the embryo originating longitudinally; evolution indefinite. Male form represented by the pollen in the anther. Female by the ovule, ultimately the seed: evolution definite, containing the oospheres in a closed oogonium.

II. SCHISTOGAMÆ.—Plants trimorphic. Neutral form originating from a fertilized oosphere, developing, like the embryo, transversely: evolution indefinite. Male form a vermiform phytozoon (spiral spermatozoid) formed within an antherocyst. Female form an oogemma, then a seminulum, with definite evolution, containing an oosphere in an open oogonium. (Characeæ.)

III. PROTHALLOGAMÆ.—Plants trimorphic. Neutral form produced from a fertilized oosphere, developing, like the embryo, transversely: evolution indefinite. Male form a vermiform phytozoon formed within an antheridium. Female form a spore, developing into a prothallus: evolution definite, containing a naked oosphere within an archegonium. (Vascular Cryptogams.)

IV. BRYOGAMÆ.—Plants trimorphic. Neutral form originating from a fertilized oosphere, developing, like the embryo, longitudinally: evolution definite. Male form a vermiform phytozoon from an antheridium. Female form a spore developing into a thallus or "cormus:" evolution indefinite, and containing a naked oosphere in an archegonium. (Muscineæ.)

V. GYMNOGAMÆ.—Plants di-, trimorphic. In the trimorphic form the neutral form is an oospore arising directly from a fertilized oosphere: evolution indefinite. Male form a zoosporiform phytozoon from an antheridium. Female form a spore developing into a thallus: evolution indefinite, containing an oosphere in a naked open oogonium. In the dimorphic plants, two sexual forms only, the male a phytozoon or pollinidium. In the monomorphic plants a single form without sexual distinction: evolution definite or indefinite. (Cellular Cryptogams.)

In the following pages the arrangement adopted is, for Dicotyledons mainly that of De Candolle, for Monocotyledons that of Bentham.

VEGETABLE KINGDOM.

Subkingdom I. **PHANEROGAMIA.** (*Flowering Plants.*)

Class I. DICOTYLEDONES. (*Exogens.*)

Subclass i. *ANGIOSPERMIA.*

Division 1. **Polypetalæ.**

Series 1. THALAMIFLORÆ.

„ 2. CALYCIFLORÆ.

Division 2. **Gamopetalæ** or **Corollifloræ.**

Series 1. INFERÆ or EPIGYNÆ.

„ 2. SUPERÆ.

„ 3. DICARPIÆ.

Division 3. **Apetalæ** or **Incompletæ.**

Series 1. SUPERÆ.

„ 2. INFERÆ or EPIGYNÆ.

Subclass ii. *GYMNOSPERMIA.*

Class II. MONOCOTYLEDONES. (*Endogens.*)

Division 1. **Petaloideæ.**

Series 1. EPIGYNÆ.

„ 2. CORONARIEÆ.

A. Syncarpiæ.

B. Apocarpiæ.

Division 2. **Spadicifloræ.**

„ 3. **Glumifloræ.**

Subkingdom II. **CRYPTOGAMIA.** (*Flowerless Plants.*)

Class I. CORMOPHYTA. (*Acrogens.*)

Division 1. **Vascularia.**

Series 1. ISOSPORIA.

„ 2. HETEROSPORIA.

Division 2. **Muscineæ.**

Class II. THALLOPHYTA. (*Thallogens.*)

Division 1. **Algæ.**

„ 2. **Fungi.**

In the following systematic description of the Natural Orders, the characters of the most important are given at length, with the necessary particulars respecting their affinities, geographical distribution, and the qualities of the more important plants they contain. To most is prefixed a short diagnosis; and a similar diagnosis, or a few explanatory remarks,

printed in smaller type, are accorded to those Orders which either are not marked by very decided characters, or which do not demand so much attention from the beginner. In most cases the views of other botanists as to the position and limitation of the groups are briefly mentioned. Under each Order are placed the names of one or more genera which furnish good illustrations and which are generally accessible for practical examination.

CHAPTER III.

SYSTEMATIC DESCRIPTION OF THE NATURAL ORDERS.

THE VEGETABLE KINGDOM.

SUBKINGDOM I. **PHANEROGAMIA, or FLOWERING PLANTS.**

Plants producing stamens and pistils in association or separately, and forming seeds containing an embryo.

CLASS I. DICOTYLEDONES.

Flowering Plants, with stems (when woody) having pith and bark separated by a compact layer of wood, which, in perennial plants, receives annual additions on the outside, beneath the bark; leaves with the ribs mostly distributed in a netted pattern and generally diminishing in size as they branch; parts of the floral circles mostly 5 or 4, or some multiple of those numbers, rarely 3; embryo with a pair of cotyledons and a radicle, which is developed into a tap-root in germination. The typically complete floral formula, supposing the parts to be uncomplicated by adhesions, irregular growth, multiplication, &c., is S5 P5 A5 G5, in regular alternation.

SUBCLASS I. *ANGIOSPERMIA.*

Flowering Plants, with the ovules formed in closed ovaries. Endosperm formed after fertilization. Pollen-cells not dividing prior to the emission of pollen-tubes (*see* under "Reproduction").

Division I. **Polypetalæ.**

Petals distinct, rarely absent or united.

Exceptions.—Hooker notes the following exceptions. Apetalous flowers occur in some species of Menispermaceæ, Caryophyllaceæ, Malvaceæ, Sterculiaceæ, Tiliaceæ, Rutaceæ, Simarubaceæ, Burseraceæ, Olacaceæ, Celastraceæ, Saxifragaceæ, Crassulaceæ, Myrtaceæ, Passifloraceæ. Apetalous flowers also may be met with in some Ranunculaceæ, Magnoliaceæ, Berberidaceæ, Sarraceniaceæ, Papaveraceæ, Cruciferæ, Canellaceæ,

Fig. 330.

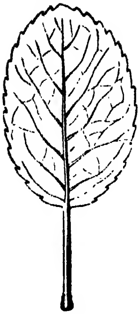


Fig. 332.

Fig. 333.

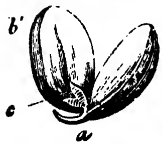


Fig. 331.

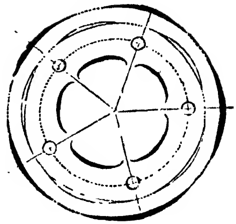


Fig. 330. Netted-veined leaf of a Dicotyledon.
Fig. 331. Quinary plan of the flower, the parts regularly alternating.
Figs. 332 & 333. Dicotyledonous embryos.

Fig. 334.

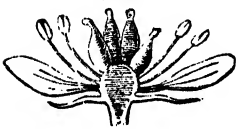


Fig. 335.

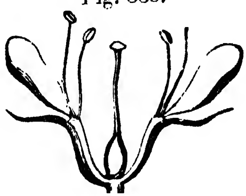


Fig. 336.

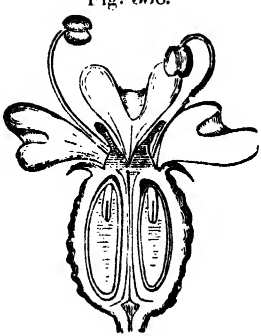


Fig. 338.

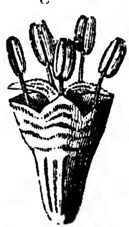
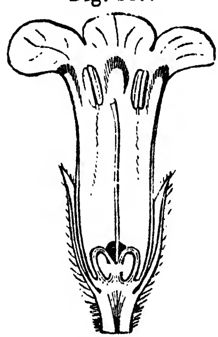


Fig. 337.



Figs. 334–338 are illustrative of the Subclasses of Dicotyledons.

Fig. 334. Thalamifloræ (*Ranunculus*).
Fig. 335. Calycifloræ, perigynous (*Prunus*).
Fig. 336. Calycifloræ, epigynous (*Fœniculum*).
Fig. 337. Corollifloræ (*Symphytum*).
Fig. 338. Incompletæ (Monochlamydeæ) (*Ulmus*).

Bixaceæ, Violaceæ, Zygophyllaceæ, Geraniaceæ, Rhamnaceæ, Sapindaceæ, Terebinthaceæ, Rosaceæ, Hamamelidaceæ, Balsamifloræ, Haloragaceæ, Gunneraceæ, Callitrichaceæ, Rhizophoraceæ, Combretaceæ, Lythraceæ, Onagraceæ, Samydaceæ, Loasaceæ, Datiscaceæ, Ficoideæ, Tetragoniaceæ, Cornaceæ, and Garryaceæ.

Plants with connate petals occur in the following usually polypetalous orders:—Anonaceæ, Pittosporaceæ, Polygalaceæ, Portulacaceæ, Tamariscaceæ, Ternstrœmiaceæ, Dipterocarpaceæ, Humiriaceæ, Diosmeæ, Balsaminaceæ, Meliaceæ, Stackhousiaceæ, Droseraceæ, Bruniaceæ, Napoleoneæ, Melastomaceæ, Turneraceæ, Cucurbitaceæ, Cactaceæ, etc.

Series I. THALAMIFLORÆ.

Calyx, corolla, and stamens usually free and springing directly from the thalamus, or from the outside of an hypogynous disk.

Exceptions.—The following are noted by Hooker. Connate sepals occur in a few orders. The calyx is adnate to the ovary, or to a fleshy thalamus in *Pæonia* (Ranunculaceæ), Calycanthaceæ, some Anonaceæ, Nymphæaceæ, Portulacaceæ, Capparidaceæ, Bixaceæ, Polygalaceæ, Ternstrœmiaceæ, Vochysiaceæ, Tiliaceæ, and Dipterocarpaceæ. The stamens are perigynous in some Dilleniaceæ, Papaveraceæ, Capparidaceæ, Moringaceæ, Resedaceæ, Violaceæ, Caryophyllaceæ, Portulacaceæ, Malvaceæ, and Sterculiaceæ.

ORDER RANUNCULACEÆ. THE CROWFOOT ORDER.

Cohort. Ranales, *Benth. et Hook.*

Diagnosis.—Herbs, or climbing shrubs, with a colourless acrid juice; leaves alternate, rarely opposite, simple or deeply divided; leaf-stalks often sheathing at the base; flowers regular or irregular,

Fig. 340.

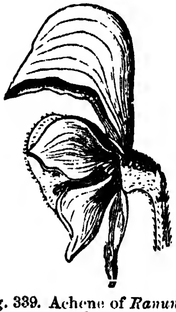


Fig. 339.

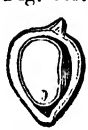


Fig. 341.

Fig. 339. Achene of *Ranunculus*, cut vertically to show the seed, with an embryo at the base of perisperm.
Fig. 340. Flower of Aconite, side view, showing the irregular petaloid calyx.
Fig. 341. The same, with the sepals removed, showing the singularly formed petals and the numerous hypogynous stamens.

polypetalous or occasionally apetalous, with the calyx petaloid; the sepals, petals, and numerous stamens all distinct and hypogynous;

carpels many or few (rarely solitary), all distinct; seed perispermic; embryo small.

Character.

Thalamus convex or flat, often elongated, very rarely concave. *Calyx* green or petaloid, regular or irregular (fig. 340); *sepals* 3–6, hypogynous, deciduous, occasionally persistent, usually imbricated in æstivation, sometimes valvate or induplicate. *Corolla*: *petals* 13–15, distinct, hypogynous, in one or more rows, sometimes deformed (fig. 341) or wanting. *Stamens* indefinite, or very rarely definite, hypogynous; *anthers* adnate, bursting longitudinally. *Ovaries* several or few, simple, 1-celled, distinct, or very rarely coherent below to form a compound many-celled ovary; *styles* simple; *cells* 1- or many-seeded; *placentas* at the ventral sutures; *ovules* anatropous. *Fruit*: a collection of dry achenes, a 1- or few-seeded berry, or a circle of follicles more or less coherent below, bursting at the ventral suture; *seeds* solitary, erect or pendulous, or rarely horizontal in two rows; *embryo* straight, minute, in the base or within the apex of horny *perisperm* (fig. 339).

Illustrative Genera.

Tribe 1. Clematideæ. *Mostly climbing plants with opposite leaves. Calyx valvate or induplicate; fruit of achenes, usually surmounted by the persistent and plumose style.*

Clematis, *L.*

Tribe 2. Anemoneæ. *Calyx usually coloured, imbricated; achenes sometimes tailed; seed inverted.*

Thalictrum, *Tournef.*
Anemone, *Haller.*
Adonis, *DC.*

Tribe 3. Ranunculeæ. *Calyx imbricated; achenes not tailed; seed erect.*

Ranunculus, *L.*

Tribe 4. Helleboreæ. *Calyx imbricated; petals irregular or none; fruit of many-seeded follicles, more or less coherent, rarely baccate.*

Caltha, *L.*
Helleborus, *Adans.*
Nigella, *Tournef.*
Aquilegia, *Tournef.*
Delphinium, *Tournef.*
Aconitum, *Tournef.*
Actæa, *L.*

Tribe 5. Pæonieæ. *Calyx imbricated; petals flat or none; carpels forming dehiscent pods, surrounded at the base by a disk.*

Pæonia, *Tournef.*

Affinities and Morphological Structure.—The typical floral formula is S 5 P 5 $\sim$ A∞ $\sim$ G ∞, the $\sim$ indicating a spiral arrangement, with vaiations, arising from suppression, multiplication, irregular growth, &c. The characters which are almost universally found are the free sepals and petals, the indefinite stamens, the inverted ovules, and the presence of perisperm. None of these, taken separately, are absolutely characteristic of the order, though collectively they are of the greatest importance. The other characters are all more or less inconstant or variable, some of the genera possessing them, others not. The conditions of the calyx and corolla, and also of the ripe fruit, are not only normally very varied in the different genera, but are readily affected and altered by cultivation.

The affinities of the Order are somewhat complex: the structure of the essential organs allies them closely to the Magnoliaceæ and Dilleniaceæ, the former of which, however, have distinct stipules, while the latter have arillate seeds; and both differ in habit. Some genera are closely related to the Berberidaceæ, from which, however, they differ in the indefinite stamens and in the sutural (not valvular) dehiscence of the anthers. From Nymphæaceæ and Papaveraceæ, which they resemble in certain respects, they are distinguished by their distinct carpels, and in the case of the Poppies by their watery (not milky) juice. Relations exist also with some Calycifloræ, as with Rosaceæ, from which the present Order is known by its hypogynous stamens, the abundant perisperm of the seeds, and the general properties. Sheathing bases of the leaves, resembling adnate stipules, occur here and in Umbelliferæ, and they somewhat resemble the stipules of *Rosa*. A kind of representation of this Order occurs among the Monocotyledons, in Alismaceæ, where the free carpels and the habit give a resemblance to those Ranunculaceæ which have a ternary calyx. The Pæonies approach the Nymphæaceæ in the disk, which is remarkably developed in *P. Moutan*, almost entirely enclosing the carpels; the stamens of Pæonies are, owing to a slight excavation of the receptacle, perigynous rather than hypogynous.

Fig. 342.

Aconitum 1

Number and Distribution.—This Order contains from 30 to 40 genera and five or six hundred species, which latter are most abundant in damp, cool climates, and are scarcely met with in the tropics, except on mountains.

Qualities and Uses.—The plants of this Order generally possess acrid and more or less narcotic-acrid properties, some being virulent poisons. The poisonous property resides in the watery juice, and is in most cases volatile, and capable of dissipation by heat, or even simple drying, and by infusion in water. It appears to be

heightened in power by acids, spirits, sugar, &c.. The species of *Ranunculus* (Crowfoots or Buttercups) are acrid when fresh, especially *R. sceleratus* and *R. Flammula.* Similar properties prevail in the tribes *Clematideæ* and *Anemoneæ*. The *Helleboreæ* are the most active of the Ranunculaceæ, the species of *Aconitum* (Monkshood) being among the most dangerous of poisonous plants, and containing an extremely powerful alkaloid, *aconitina*. The species of this genus appear to differ in the quality of their juices when grown under varied conditions, somewhat like the Hemp-plant, since the roots of the most poisonous of them are said to be eaten with impunity in the higher parts of the Himalayas. *A. Napellus* (fig. 342) and *A. Cammarum* (*paniculatum*) are well-known poisonous European Monkshoods; and, according to Dr. Hooker, the celebrated "Bikh" poison of India is obtained indiscriminately from *A. Napellus, luridum,* and *palmatum*, as well as from *A. ferox*, L., which was supposed to be the sole source. The yellow *A. Lycoctonum* of Central Europe is far less active. The seeds of *Delphinium Staphisagria* (Stavesacre) are drastic purgatives and emetics; the Hellebores (*Helleborus niger, orientalis,* and *fœtida* especially) are likewise violent evacuants, and the Pæonies fall into the same category. The berries of the *Actea* are poisonous. Some of the milder plants are used as tonics, on account of the powerful bitter they contain, as the Yellow-root (*Hydrastis canadensis*) and the Gold-thread (*Coptis trifoliata*), both North-American plants. The pungent seeds of *Nigella sativa* were formerly used as pepper. The root of *Actæa racemosa* is used medicinally under the name *Radix Cimicifugæ.*

Many of the Ranunculaceæ are favourite garden plants: for example the species of *Clematis, Anemone, Ranunculus, Eranthis* (Winter Aconite), *Helleborus, Nigella, Aquilegia* (Columbines), *Delphinium* (Larkspurs), *Aconitum* (Monkshood), and *Pæonia.*

DILLENIACEÆ are trees or shrubs mostly with alternate leathery feather-veined leaves, generally destitute of stipules; an imbricated 5-merous calyx and corolla (the former persistent); numerous hypogynous stamens; solitary, few, or numerous, distinct or rarely coherent carpels; seeds several, 2, or 1 by abortion, arillate; perisperm fleshy.—Illustrative Genera: *Dillenia*, L.; *Hibbertia*, Andr.; *Candollea*, Labill.

Affinities, &c.—Connected with Ranunculaceæ by many important points of structure, these plants are at once distinguishable by the arborescent habit, the persistence of the calyx and the stamens, and the arillate seed; they are even nearer to the Magnoliaceæ, but have no stipules, and the plan of the flower is here 5-merous; they are also related to the Anonaceæ, which, however, have a valvate calyx and ruminated perisperm. Some of the genera (*Hemistemma, Pleurandra*) have all the stamens on one side of the flower; others have them united into separate bundles, probably representing so many divided stamens. A relationship between this Order and the Ternstrœmiaceæ is established by the genus *Sauraja.*

Number and Distribution.—A small group of 17 genera and about 180 species, which are natives chiefly of India, South America, and Australia; a few also of Africa, between the tropics.

Qualities and Uses.—The general character of this Order is astrin-

gency, which renders some of them valuable in Brazil. Some of the *Dilleniæ* are valued in India for their acid juices.

Most of the species of *Dillenia* are very handsome, both as to foliage and blossom; and some of the larger kinds yield hard, durable timber; several species are cultivated in large collections of stove or greenhouse plants in this country, where they are evergreen shrubs; *Delima* and *Tetracera* are stove climbers.

MAGNOLIACEÆ are trees or shrubs, often aromatic, with the leaf-buds mostly sheathed by membranous stipules; leaves alternate, simple; flowers regular, polyandrous, polygynous; thalamus convex, often elongated; calyx and corolla usually coloured alike, in three or more 3-merous circles, imbricated; fruit of numerous dry or succulent, dehiscent or indehiscent carpels; seeds often with a fleshy testa like an aril, and suspended by a long funiculus; perisperm fleshy, homogeneous.—Illustrative Genera: Tribe 1. MAGNOLIEÆ: carpels on a lengthened thalamus, leaves scarcely dotted: *Magnolia*, L. Tribe 2. WINTEREÆ: carpels in a circle; leaves with transparent dots; stipules often wanting: *Drimys*, R. Br.

Affinities, &c.—Closely related to Dilleniaceæ, this Order is distinguished by the 3-merous flowers, and in many cases by its stipules; from the Anonaceæ it is separated by its imbricated corolla and its homogeneous perisperm. The convolute stipules enclosing the leaf-buds of *Magnolia* remind us of the stipules of *Ficus* and other Urticaceæ. In *Magnolia* the course of development shows that the stipules arise from the edges of the leaf-stalk, and that their originally free edges become combined to form a sheath over the bud. The character of the flowers indicates a relationship with Schizandraceæ.

Number and Distribution.—A small group of 8 or 9 genera, and 70–80 species, the greater number of which belong to the Southern States of North America; some occur also in the West-India Islands, in Japan, China, and India. *Drimys* and *Tasmannia* belong to the extreme south of South America, to Australia, and New Zealand.

Qualities and Uses.—Bitter tonic properties in the bark and excessively fragrant blossoms are the most striking qualities of the plants of this Order, which are chiefly handsome trees or shrubs, with broad shining foliage and often very large flowers. The barks of *Magnolia glauca, grandiflora, Frazeri*, &c. are used in the United States as aromatic tonics; *Michelia montana, Aromodendron elegans*, and *Liriodendron tulipifera* have similar properties. The odour of *Magnolia grandiflora*, and of *M. glauca* and *M. tripetala*, is so powerful as to become very oppressive in close places; the last two often induce headache. The species of *Illicium* are aromatic: *Illicium anisatum*, Star-Anise, is so called from the flavour of aniseed in the whole plant, especially the fruit, which yields an aromatic oil. *I. floridanum* has similar properties; and the seeds of *I. religiosum* are burnt by the Chinese for incense. The bark called Winter's bark is that of *Drimys Winteri*; and other species of *Drimys* and *Tasmannia* have similar aromatic and tonic properties. Some of the larger species of *Magnolia, Michelia*, and other genera are valued as timber trees in India. Many plants of this Order are cultivated in this country

on account of their beauty or fragrance; some are hardy, as various Magnolias and the Tulip-tree (*Liriodendron*) from North America. Some of the Chinese and Himalayan Magnolias have deciduous foliage and magnificent flowers, such as *M. Campbelli* and *M. Yulan*; others are greenhouse or stove shrubs, such as the species of *Illicium* and the more tender Magnolias.

ANONACEÆ. THE CUSTARD-APPLE ORDER.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with naked buds and no stipules; thalamus usually prominently convex; calyx of three sepals; corolla of six petals in two circles, usually valvate in the bud, hypogynous, sometimes coherent; stamens with an enlarged connective, mostly indefinite, on a large torus; carpels usually numerous, separate or cohering; seed with ruminated perisperm.—Illustrative Genera: *Bocagea*, St.-Hil.; *Xylopia*, L.

Affinities, &c.—This Order is separated from the Magnoliaceæ in general by the absence of stipules, the valvate æstivation of the corolla, and the form of the anthers; but stipules are not universal in the Magnoliaceæ, nor is the corolla always valvate here. The most characteristic features in the Anonaceæ are the trimerous flowers, the double corolla, the form of the anthers and carpels, and the ruminated perisperm, which latter indicates a relationship to the Myristicaceæ, an apetalous Order. Several remarkable deviations from the general character of the Order exist, such as the coherent condition of the horn-like petals in *Rollinia*, the definite number of stamens and carpels in *Bocagea* (which is related to the Berberidaceæ and the Menispermaceæ), and the concave thalamus, the sepals and petals combined to form a hood, and the perigynous stamens of *Eupomatia laurina*. *Monodora* has a single carpel.

Number and Distribution.—Genera about 40, species about 400; natives of the tropical regions of Asia, Africa, and America.

Qualities and Uses.—The Anonaceæ are allied to the Magnoliaceæ by their general aromatic and fragrant properties. The dry fruits are mostly aromatic and pungent, while the succulent kinds are sweet and agreeable esculent fruits. The Custard-apples, Sweet-sops, and Sour-sops of the West Indies, and the Peruvian Cherimoyas are the fruits of species of *Anona*. The fruits of *Xylopia aromatica* are used as pepper by the African negroes (*Piper æthiopicum*). *Monodora Myristica*, the Calabash Nutmeg, has qualities resembling the true Nutmeg. Lance-wood, used for making shafts, bows, &c., is said by Schomburgk to be the wood of *Duguetia quitarensis*. Some of the species of *Anona*, *Uraria*, *Xylopia*, &c. are sometimes cultivated in stoves in this country, forming evergreen shrubs.

MONIMIACEÆ are aromatic trees or shrubs with opposite leaves without stipules; flowers axillary, diclinous; thalamus concave, perianth in 1 or 2 circles, tubular below; stamens numerous, springing from the tube; ovaries several, free, and distinct, enclosed in the tube of the thalamus, 1-celled, 1-seeded; seeds pendulous; embryo minute, with thin

spreading cotyledons, on the outside of abundant fleshy perisperm.—This is a small Order of plants belonging chiefly to South America, but occurring also in Madagascar, Java, Australia, &c.; sometimes combined with the next family, and usually referred to the neighbourhood of Lauraceæ, from which they are distinguished by their apocarpous ovaries, but, like the Atherospermaceæ, standing properly in their vicinity of the Anonaceæ, along with Myristicaceæ; for some genera are dichlamydeous. They are also related to Calycanths and Roses, but they differ from these Orders in their opposite exstipulate leaves and albuminous seeds. Baillon unites them with Calycanths and Atherosperms, and places them near Magnoliaceæ, to which their aromatic properties ally them. They are not of importance economically; the fruit of *Boldoa* is eaten in Chili.—Genera: *Monimia*, Thouars; *Citrosma*, R. & P.; *Boldoa*, Juss., &c.

MENISPERMACEÆ. The Moon-seed Order.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Woody climbers, with palmate or peltate alternate leaves, without stipules; flowers diœcious, rarely perfect or polygamous; sepals and petals similar, in three or more circles, imbricated or valvate in the bud; stamens usually 6, superposed to the sepals and petals; pistils 3–6-gynous, on a small thalamus; fruit a 1-seeded drupe, with a large or long curved embryo in scanty perisperm.—Illustrative Genera: *Jateorrhiza*, Miers; *Menispermum*, Tournef.; *Cissampelos*, L.; *Cocculus*, DC.

Affinities, &c.—This curious Order is related to the Anonaceæ and the Berberidaceæ through *Bocagea*, especially when the flowers are perfect. Its nearest neighbours are Lardizabalaceæ and Schizandraceæ, with which the plants agree much in habit. All these approach the Magnoliaceæ; but the habit, the generally unisexual flowers, and the absence of stipules separate them from that family. This Order is very heteromorphous in almost all parts of its structure. The peculiar organization of the wood and foliage deserves attention.

Number and Distribution.—Genera about 30; species (under a hundred) are natives of the tropics of Asia and America, forming woody climbers of great size in the forests. A few are found in more temperate regions, but none in Europe.

Qualities and Uses.—Narcotic and bitter properties of considerable power occur in this Order. "Cocculus Indicus," containing the poisonous principle picrotoxine in the seeds, consists of the berries of *Anamirta cocculus*; *Jateorrhiza palmata* or *Calumba* furnishes "Calumba-root;" different species of *Cissampelos*, as well as *Chondodendron tomentosum*, the roots of which furnish Pareira brava, are used as tonics and diuretics. In India the seeds and roots of "Gulancha," *Tinospora cordifolia*, are used for similar purposes. Species of *Cocculus* and *Cissampelos* are grown in stoves in this country; some of the North-American *Menisperma* grow as hardy climbers here.

LARDIZABALACEÆ constitute a small group, referred by Bentham and Hooker, as also by Baillon, to Berberids, and by De Candolle to

Menisperms. From the former they differ in their diclinous flowers, monadelphous stamens, sutural dehiscence of the anthers, and more numerous ovaries. From the latter they differ in their more numerous ovules and small embryo in copious solid perisperm.—Illustrative Genera: *Hollbœllia*, Wall.; *Stauntonia*, DC.; *Lardizabala*, Ruiz et Pav.

The species are mostly from the cooler parts of Asia and South America. The berries of some are edible. *Hollbœllia* and *Stauntonia* (Nepal) have been introduced as greenhouse evergreen climbers, and are hardy in the south of England.

SCHIZANDRACEÆ form a small family regarded by Bentham and Hooker as a tribe of Magnoliaceæ, from which they differ merely in their climbing habit, exstipulate leaves, diclinous flowers, and fleshy 2–3-seeded carpels.—Illustrative Genera: *Kadsura*, Juss.; *Schizandra*, L. C. Rich.

The species belong to India, Japan, and the S. United States. They are insipid and mucilaginous. *Schizandra coccinea* (North America) is a handsome greenhouse plant; *Sphærostema* (Nepal) has been introduced in stoves.

SABIACEÆ are a small Order of East-Indian plants, related to the Anacardiaceæ, and particularly to the Menispermaceæ, in the circumstance that the sepals, petals, stamens, and ovaries are all superposed to each other, but they have 5-merous hermaphrodite flowers and a syncarpous pistil. By Bentham and Hooker they are placed near Sapindaceæ.

BERBERIDACEÆ. The Berberry Order.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Shrubs or herbs, with regular hermaphrodite flowers, with the sepals and petals both imbricated in the bud in 2 or more circles of 2–4 each (fig. 343); hypogynous stamens as many as the petals and superposed to them; anthers opening by 2 recurved valves. Carpel solitary, free; fruit baccate or dry; embryo straight in perisperm.—Illustrative Genera: *Berberis*, L.; *Epimedium*, L.

Affinities, &c.—To Ranunculaceæ this Order is related closely by *Jeffersonia* and *Podophyllum*. *Epimedium* allies the order to Fumariaceæ. The apparent superposition of parts is here due to the decussation of whorls (fig. 343). The connexion with the Anonaceæ through *Bocagea* has been referred to above. They differ from Menisperms, to which their floral arrangements ally them, in their hemaphrodite flowers and small embryo. The remarkable mode of dehiscence of the anthers connects this Order in that respect with Lauraceæ and Atherospermaceæ among the Monochlamydeæ. *Caulophyllum thalictroides*, a North-American plant, is interesting from the development of its fruit: the pericarp dehisces very early, and the two seeds burst out and ripen into naked berry-like bodies with a succulent testa. The leaves of these plants are simple or

Fig. 343.

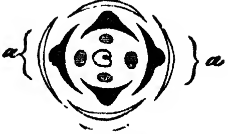


Diagram of the flower of *Epimedium*: *a*, *a*, bracteoles.

compound, sometimes reduced to the condition of spines. The ripe anthers possess a peculiar irritability, which causes their valves to turn back and burst when touched, so as to allow of the emission of the pollen.

Distribution.—A small Order of about 12 genera and under a hundred species, which are natives of temperate climates in America, Europe, and the northern part of India.

Qualities and Uses.—The bark of the root of some of the Indian species contains a bitter principle, on which account it is used as a tonic in fevers in lieu of quinine. The "Lycium" of the ancients was identical with the extract prepared in India from the wood or root of several species of *Berberis*. The Berberry (the fruit of *Berberis vulgaris*) and the fruits of other species are acid and astringent, and are eaten preserved. The stem and bark are used by dyers, both on account of their astringent properties and as ingredients in a yellow dye. The rhizome of *Podophyllum peltatum* furnishes a resin which has purgative properties, and is much used as a substitute for mercury. The leaves of this plant are narcotic; but the berries are edible. *Berberis vulgaris* is a British plant, often cultivated on account of its beautiful scarlet berries; the evergreen Berberaceæ, *B. Aquifolium*, &c. (*Mahonia*, Nutt.), are also extensively planted on account of their shining pinnate leaves and the grey bloom on their black berries. *Epimedium alpinum* is a rare British plant, found in the northern counties.

NYMPHÆACEÆ. WATER-LILIES.

Coh. Ranales, *Benth. et Hook.*

Diagnosis.—Aquatic herbs with cordate or peltate floating leaves, and solitary showy flowers, proceeding from a rhizome growing at the bottom of the water; the partially petaloid sepals and the numerous petals and stamens imbricated in several rows partially or wholly emerge from a large fleshy disk; the numerous carpels combined into a many-celled compound ovary, with radiating stigmas on the top; ovules all over the spongy dissepiments; embryo minute, enclosed in a separate sac at the end of the copious perisperm.—Illustrative Genus: *Nymphæa.*

Affinities, &c.—The relations of this striking Order are varied, and some difference of opinion exists among botanists even as to their position in the two great classes of Angiospermous Flowering plants. The embryo appears to be truly Dicotyledonous; and they naturally approach the Papaveraceæ in the character of the ovary, and the Pæony tribe among the Ranunculaceæ, especially the kinds with a highly developed disk. The character of the floral envelopes and stamens allies them to Magnoliaceæ. The Nelumbiaceæ and Cabombaceæ are immediately connected with them. From a mistaken view of the structure of the seed, regarding the vitellus or amniotic inner endosperm as a cotyledon, Richard assumed that this Order was Monocotyledonous; and although it has proved that this account of the structure of the embryo was incorrect, the plants are so anomalous in many respects, that it is difficult to decide as to their closest relationships. The structure of the rhizomes is quite that of

Monocotyledonous stems; the habit relates them to the Hydrocharidaceæ; and the structure of the ovaries indicates some affinity with Alismaceæ. When, however, we regard the Dicotyledonous embryo and its germination, the quaternary or quinary plan of the flowers, and the netted ribbing of the leaves, together with the close relation to the Dicotyledonous Orders above named, the balance of characters is strongly in favour of its reference to this class. Nymphæaceæ are very interesting in structural respects—as, for example, in the anomalous condition of the rhizomes, the remarkable development of the leaves in *Victoria*, the curious succession of forms between petals and stamens in the flowers of *Nymphæa* and *Victoria*, the various degrees of development of the disk and enlarged receptacle, ranging from *Nuphar* with a superior ovary to *Victoria* with its ovary sunk in the receptacle and its stamens and envelopes raised on an annular disk, the seeds growing all over the dissepiments, and in the peculiar condition of the albumen. *Barclaya* has united petals.

Distribution.—A small family of 4 or 5 genera and 30 to 40 species, which are distributed throughout the world, more rarely in the southern hemisphere.

Qualities and Uses.—These plants are said, on doubtful authority, to be sedative and narcotic. More important characters arise from the presence of starch in the seeds of various kinds of *Nymphæa*, of *Euryale* and *Victoria*, which are used as food. The rhizomes of some Nymphæas are eaten in Scinde, others in Western Africa. Among the most remarkable plants of the Order is the *Victoria regia*, a native of the rivers of equatorial America, with its enormous circular leaves and beautiful flowers. Our native Water-lilies, the white (*Nymphæa alba*) and yellow (*Nuphar lutea*), are both striking objects, and the cultivated *Nymphæa cærulea* and the crimson *N. rubra* illustrate the brilliancy and variety of colour in this beautiful Order. *N. gigantea*, a blue-flowered Australian species, has flowers almost as large as those of the *Victoria*.

CABOMBACEÆ, consisting of only two species, of the genera *Cabomba* and *Brasenia* (*Hydropeltis*), are sometimes separated from Nymphæaceæ, of which they are a reduced form, with definite sepals and petals, hypogynous stamens, distinct carpels provided with styles, inserted on a flattened torus, and containing one or two ovules on the dorsal suture. They are closely allied to Ranunculaceæ, but differ in the embryo enclosed within a double albumen. Both genera occur in America, and *Brasenia* also in the East Indies and Australia.

NELUMBIACEÆ are large aquatic plants, like Water-lilies, but with distinct carpels, forming acorn-shaped nuts separately imbedded in cavities of a large top-shaped thalamus. Seeds solitary, aperispermic. This Order consists apparently of the two species of the one genus *Nelumbium*—*N. speciosum*, supposed to be the Sacred Egyptian Bean, found throughout the East Indies, but no longer met with in Egypt, and *N. luteum* in North America. They are nearly related to Nymphæaceæ, through Cabombaceæ; and both are included in that family by Bentham and Hooker. The enlarged receptacle of the flower is very curious, and the peltate leaves raised above the water on long stalks are remarkable objects. The nuts

are the ripened carpels, which are contained in separate sockets in the top of the thalamus; the seeds have large flat fleshy cotyledons applied against the plumule, which is unusually developed. The seeds, as also the tubers of *N. luteum* and the rhizomes of *N. speciosum*, are esculent, being full of farina at certain seasons.

SARRACENIACEÆ are polyandrous and hypogynous Bog-plants, with hollow pitcher-shaped or trumpet-shaped leaves, and regular polyandrous hypogynous flowers.—Illustrative Genera: *Sarracenia*, L.; *Darlingtonia*, Torr.

Affinities, &c.—These curious plants, chiefly remarkable for their anomalous leaves, forming *ascidia* or pitchers, are few in number, consisting of a few species of *Sarracenia* in the United States, a *Darlingtonia* in California, and *Heliamphora* in Guiana. *Sarracenia* has a very large, angular, peltate stigma, while that of *Heliamphora* is simple and truncate. They are regarded as related to Ranunculaceæ by the 4–5-merous and imbricated envelopes and the numerous hypogynous stamens, while the coherence of the carpels into a compound ovary brings them at the same time near Papaveraceæ; but the placentas are axile. The pitchers are in this case formed by the disproportionate growth of the marginal as contrasted with the central portions of the leaf. They secrete a digestive fluid which causes the solution of insects, &c., which find their way into the pitchers, and which solution is in time absorbed by them.

PAPAVERACEÆ. The Poppy Order.

Coh. Parietales, *Benth. et Hook.*

Diagnosis.—Herbs with milky (white or coloured) juice, alternate exstipulate simple or lobed leaves; flowers regular, 2-merous or 4-merous; sepals caducous; stamens polyandrous, hypogynous, rarely perigynous; ovary syncarpous, 1-celled, with 2 or many parietal placentas.

Character.

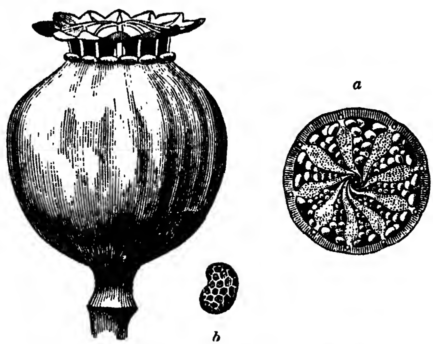
Thalamus flat or expanded. *Calyx*: *sepals* 2, rarely 3, caducous. *Corolla*: *petals* 4, rarely 6, hypogynous, mostly crumpled up in æstivation. *Stamens* free and distinct, indefinite, hypogynous; *anthers* 2-celled, bursting longitudinally. *Ovary* free, composed of 2 or more carpels (very rarely distinct), 1-celled; *ovules* numerous, very rarely solitary; *placentas* broad, parietal, on the projecting incomplete dissepiments; *style* short or none; *stigmas* radiating, double, opposite the imperfect dissepiments; *ovules* anatropous or amphitropous. *Fruit* capsular (fig. 345) with a number of placentas on imperfect septa, or pod-shaped with parietal placentas, the dehiscence valvular or porous; *seeds* mostly numerous; *embryo* minute, straight, at the base of fleshy oily perisperm.—Illustrative Genera: *Chelidonium*, Tournef.; *Papaver*, Tournef.; *Glaucium*, Tournef.

Affinities, &c.—The typical floral formula is $\widehat{S\,2}\ P\,4 \backsim A\,\infty\ \widehat{G\,2}$. Taking the common Poppies as types of this order, we find a marked distinction from Ranunculaceæ in the 2-merous calyx, the confluent carpels, and the milky juice; but the first two of these characters do not hold universally, since *Argemone* has sometimes 3 sepals, and *Platystemon* has the carpels more or less distinct, or united only slightly externally. *Bocconia*, with small flowers and no petals, approaches to *Thalictrum*; it has but a single carpel. Monstrous capsules of *Papaver* occur in gardens with the carpels partly free, somewhat as in *Nigella*. This Order is also related to the Nymphæaceæ by the general structure of the flower of *Papaver*; and the dissepiments extend quite to the axis in the Californian genus *Romneya*.

Fig. 344.

Papaver somniferum.
The Opium Poppy.

Fig. 345.



Capsule of Poppy (*Papaver*): *a*, transverse section; *b*, seed.

Another genus from the same region, *Dendromecon*, has peculiar double-lined parietal placentas, and the capsule bursts into 2 valves with the seeds on the margins, as in Cistaceæ. The quaternary arrangement of the floral envelopes and the pod-shaped ovary of *Eschscholtzia*, *Glaucium*, *Chelidonium*, &c. cause a close resemblance to Cruciferæ and Capparidaceæ, from which, however, there is a marked distinction in the perispermic seeds and the narcotic milky juice. The tetradynamous stamens of Cruciferæ, too, almost always afford a striking character: but a remarkable exception is supplied by an East-Indian polyandrous Crucifer (*Megacarpæa polyandra*), whose stamens are numerous like those of a Poppy. The nearest relatives of the Papaveraceæ are the Fumariaceæ,

which are combined with them as an irregular form by some authors. The agreement is great in many respects; but the Fumariaceæ have irregular flowers, diadelphous stamens, and a watery juice: the genus *Hypecoum*, however, has the corolla nearly regular, and its 4 stamens are distinct; and *Meconella*, in the present Order, has but 4–5 stamens; so that *Hypecoum* is midway, as it were, between the Orders.

The structural points most worthy of note are the varied conformation of the ovary, and the peculiar construction of the stigmas by two lamellæ from adjoining carpels. There is a curious enlargement of the receptacle of *Eschscholtzia*, with circumscissile separation of the coherent caducous sepals in the form of a conical cap. The stamens and petals, moreover, become perigynous in this genus. The sepals in most cases fall off when the flowers expand, so that they must be observed in unopened flowers. In *Eschscholtzia* the receptacle is at first flat with two sepals, which become connate, four petals, three rows of stamens, and four carpels, of which two are abortive (M. T. M.).

Distribution.—The group is not a large one; but the species occur in all parts of the globe, but sparingly out of Europe (in a wild state).

Qualities and Uses.—The milky or coloured juice of Papaveraceæ is generally powerfully narcotic, sometimes acrid. *Papaver somniferum*, the Opium Poppy (fig. 344), is the most important plant of the Order, the opium consisting of the dried milky juice obtained from the unripe capsules (fig. 345). Its native country is unknown; but it is largely cultivated in Turkey and the East Indies. Its seeds yield a fixed oil, which is quite harmless and is used both by itself and as a means of adulterating olive-oil; the oil-cake is also used for feeding cattle. The seeds of *Argemone mexicana* are narcotic-acrid. The yellow acrid juice of *Chelidonium majus*, as also that of *Bocconia frutescens*, is poisonous, and is sometimes used as an escharotic. *Sanguinaria canadensis*, the Blood-root or Puccoon, receives the former name from the red juice of its root, which is employed in North America for its emetic and purgative properties. *Meconopsis nepalensis* is said to be very poisonous, especially in the roots.

Several plants of this Order are wild in this country, as the four kinds of Red Poppy of our fields, the commonest of which is *Papaver Rhœas*. *P. somniferum* is a corn-field weed in many places on chalky soil; and its numerous double varieties are to be found in most gardens. *Glaucium luteum*, the yellow Horned Poppy, grows on our sea-shores; *Chelidonium majus* grows about hedges near villages, and is apparently an outcast from gardens; the other native plants of this Order are less common. *Eschscholtzia*, a Californian genus, is now found in every garden; and *Platystemon*, *Argemone*, and other genera are also cultivated here.

FUMARIACEÆ. The Fumitory Order.

Coh. Parietales, *Benth. et Hook.*

Diagnosis.—Delicate smooth herbs with watery or colourless juice, dissected leaves, irregular flowers, with 4 partially united petals, 6 diadelphous or 4 distinct stamens; ovary 1-celled, 1-seeded, or several-seeded with two parietal placentas.

Character.

Thalamus small. *Calyx*: *sepals* 2, caducous. *Corolla*: *petals* 4, irregular, in 2 circles. *Stamens* hypogynous, rarely 4 and distinct, opposite to the petals, or 6, diadelphous, the parcels opposite to the outer petals, each with a central 2-celled anther and 2 lateral 1-celled anthers. *Ovary* free, 1-celled; *style* filiform; *stigma* with 2 or more points; *ovules* horizontal, amphitropous. *Fruit*: an indehiscent 1- or 2-seeded nut, or a dry 2-valved or succulent indehiscent many-seeded pod; *seeds* shining, mostly arillate; *embryo* minute, abaxial, straight or curved, in fleshy perisperm.—Illustrative Genera: *Dicentra*, Borkh.; *Fumaria*, Tournef.; *Hypecoum*, Tournef.

Affinities, &c.—The close relationship to Papaveraceæ has been pointed out. Bentham and Hooker indeed include Fumitories under that family. *Hypecoum*, with its four distinct stamens, diverges from the ordinary type immediately towards that Order. The number, form, and arrangement of the floral envelopes mark an affinity to the Berberidaceæ, which likewise have stamens opposite to the petals. A further relationship exists in the direction of Cruciferæ, concerning which, however, authors are at variance, on account of the curious condition of the diadelphous stamens here. The view taken of the morphology of these flowers by Payer, Eichler, Caruel, and others is that there are two sepals formed successively, two outer petals formed simultaneously, two inner petals also formed simultaneously, two outer staminal tubercles, each of which becomes three-lobed; a second staminal whorl is abortive—$S\,2\;\;P\,2+2\;A\,2+2\;\overset{\frown}{G\,2}$. The trilobation of the petals of *Hypecoum* is analogous with that of the stamens. [In *Dielytra* I find in the course of development two sepals, four petals in two rows, two "compound stamens" (of which the central lobe is largest and bears a two-celled anther, while the lateral ones have but a single anther-lobe), and two carpels.—M. T. M.] The mode in which the horned stigmas push themselves against the extrorse anthers in the blossom of *Fumaria*, while the petals cohere by their tips, is worthy of examination, as also are the modifications of the staminal bundles in *Fumaria*, *Dicentra*, &c. The long pod of *Hypecoum* has transverse spurious septa between the seeds. The pollen of *Fumaria* is polyhedric.

Distribution.—The species are not very numerous, and are mostly found in the temperate parts of the Northern Hemisphere.

Qualities and Uses.—Mild bitter, sometimes rather acrid, and with slight diaphoretic and aperient properties, but of little importance in this respect. The genus *Fumaria* has a number of rather doubtful species in this country; *Corydalis claviculata* is not very rare in woody places, and several tuberous-rooted species of *Corydalis* are found as hardy herbaceous plants in our gardens. *Dicentra* (*Dielytra*) *spectabilis*, a handsome Chinese species, is now greatly cultivated as an early-flowering greenhouse plant, but it is hardy in some situations.

CRUCIFERÆ. Cross-flowers.

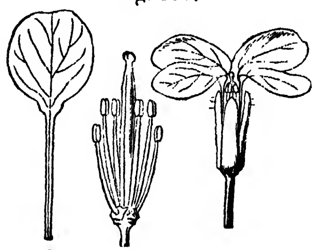
Coh. Parietales, *Benth. et Hook.*

Diagnosis.—Herbs with a pungent watery juice, cruciform 4-merous flowers, tetradynamous stamens, a siliquose or siliculose fruit, and aperispermic seed.

Character.

Calyx: *sepals* 4, deciduous, imbricated or valvate in the bud. *Corolla*: *petals* 4, distinct, stalked, arranged in the form of a cross, alternating with the sepals (fig. 346). *Stamens* tetradynamous (fig. 347), a single short one opposite each lateral sepal, and a pair of long ones opposite the anterior and the posterior sepals, with small *glands* intervening between the stamens on the receptacle. *Pollen* generally ovoid, with three folds. *Ovary* solitary, 2-celled by a spurious dissepiment (*replum*) extending across from the middle line of the two parietal placentas; *stigmas* 2, sessile, opposite the

Fig. 346.



b c a

Raphanus: *a*, cruciform flower; *b*, stalked petal; *c*, tetradynamous stamens.

Fig. 349.

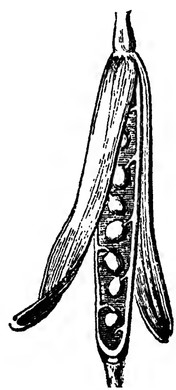


Fig. 347.

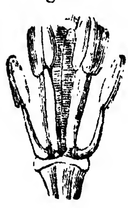


Fig. 348.

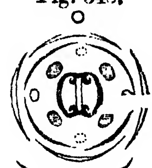


Fig. 347. Stamens and pistil of *Cheiranthus*.
Fig. 348. Ground-plan of the flower of *Cheiranthus*: *x*, the front; O, the position of the axis.
Fig. 349. Burst silique of *Sinapis*.

placentas. *Fruit*: a *silique* (fig. 349) or a *silicle* (fig. 350), usually 2-celled by the replum, from which the valves separate in dehiscence, leaving the placentas as a frame: or 1-celled from the imperfection of the replum (fig. 350), and indehiscent or breaking across at constricted places; *seeds* generally pendulous in a single row on each placental margin, the two rows either intercalated in one line or in two collateral lines on the replum; *embryo* with the radicle variously folded on the cotyledons, without perisperm.

Fig. 350.

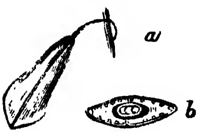


Fig. 351.

Fig. 352.

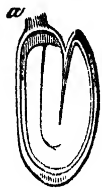


Fig. 350. Silicle of *Isatis*: *a*, entire; *b*, cross section.
Fig. 351. Burst silicle of *Thlaspi*.
Fig. 352. Seed of *Erysimum* cut vertically: *a*, funiculus.

De Candolle divided this large and very natural Order into Suborders, founded on the mode of folding of the embryo, thus:— 1. *Pleurorhizæ* (O =), with the radicle turned round the sides or edges of the flat, accumbent cotyledons; 2. *Notorhizæ* (o ||), with the radicle folded against the back of one of the flat, incumbent cotyledons; 3. *Orthoploceæ* (o > >), the radicle similarly folded, but the incumbent cotyledons longitudinally folded (induplicate) so as partly to surround it; 4. *Spirolobeæ* (o || ||), the cotyledons linear, incumbent, and folded or rolled over on themselves and against the radicle; 5. *Diplecolobeæ* (o || || ||), the cotyledons linear incumbent, and twice or thrice transversely folded.

Some writers have established Suborders on the characters of the fruit, using those of the embryo for subdivision, thus:—1. *Siliquosæ*, with a silique opening by valves; 2. *Siliculosæ latiseptæ*, with a silicule opening by valves, the replum in the broader diameter; 3. *Siliculosæ angustiseptæ*, a valved silicule with the replum in the narrower diameter; 4. *Nucumentaceæ*, with an indehiscent silicule, often 1-celled without a replum; 5. *Septulatæ*, with the valves bearing transverse septa in the inside: 6. *Lomentaceæ*, with a pod breaking across into 1-seeded pieces, sometimes with a 1-2-, seeded beak above the abortive true pod. Bentham and Hooker's arrangement closely corresponds with this: but the Suborders are all more or less artificial.

ILLUSTRATIVE GENERA: *Cheiranthus*, R. Br.; *Arabis*, L.; *Alyssum*, L.; *Erophila*, DC.; *Cochlearia*, L.; *Iberis*, L.; *Cakile*, Tournef.; *Erysimum*, L.; *Capsella*, Vent.; *Lepidium*, R. Br.; *Brassica*, L.; *Crambe*, Tournef.; *Raphanus*, Tournef.; *Subularia*, Adans.; *Schizopetalon*, Hook.

Affinities, &c.—The relationships of this Order to Papaveraceæ and Fumariaceæ, and thence with the apocarpous Orders standing near, have been dwelt on already. With the Capparidaceæ the agreement is still closer, in the general character of the flower and in the seeds; but when that Order has so few as six stamens they are not tetradynamous—an almost universal condition in Cruciferæ. The true nature of the plan of the anomalous flower of this Order is a subject of considerable controversy. The numerical arrangement is $S\,2+2\ P\,4\ A\,2+4\ \overset{\frown}{G\,2}$, disposed thus:—S.. + : P : : A.. + : : G... The two lateral sepals are attached higher up than the other two, the four petals are in a single whorl. Lindley and many others regard the six stamens as belonging to two circles of four, the outer of which has always two stamens abortive, while the inner pairs should normally stand singly before the four petals. If the glands in the receptacle are to be regarded as abortive stamens, which is plausible, this structure really does exist in *Erysimum Peroffskianum*, where the two glands stand opposite two sepals and form a circle with the two short stamens; but there appears to be as many as six glands in some Crucifers, which involves the existence of three staminal circles: as a polyandrous form (*Megacarpæa polyandra*) has been met with, we may even admit this. De Candolle, Moquin-Tandon, and Webb regarded the stamens as normally four, the pairs being formed by *chorisis*. As to the ovary, it is explained as being composed of two carpels with a spurious dissepiment; the stigmas opposite the placentas, like those of *Papaver*, being double and composed of a half from each carpel, just as the placentas are. The fact that four carpels are sometimes found in monstrosities, and are constant in the genus *Tetracellion*, merely indicates a return to a symmetrical condition, ordinarily interfered with by suppression of two carpels. The most recent views as to the structure of the flower are those of Eichler, who affirms the existence of chorisis in the long stamens. His notion is that the flowers of Crucifers consist of two antero-posterior sepals, two lateral ones, four petals crossing the lateral sepals diagonally, two lateral short stamens, two antero-posterior long stamens split into two, and two lateral carpels; $S\,2+2\ P\,4\ A\,2+2\ \overset{\frown}{G\,2}$. These views are adopted after an examination of the development of the flower, in which there are first to be seen two tubercles for the fore and aft sepals, then two for the lateral sepals; the four petals originate simultaneously; the two short stamens arise opposite the lateral sepals, the two other staminal tubercles are subsequently developed at a higher level than the preceding and decussate with them; these two after a time become notched, the notch gradually deepens and ultimately forms two distinct stamens. The position of the carpels is sometimes antero-posterior (:) sometimes lateral (..). The glands of the disk also vary in number and position, and may, as suggested by Mr. Worthington Smith, be the representatives of abortive stamens or pistils, which would, if fully developed, render the flower symmetrical and isomerous. Van Tieghem considers the gynæcium to consist of four carpels, two of which are ovuliferous and terminate in stigmas, while the other two are sterile.

Rev. G. Henslow suggests that the original type was not binary or quaternary as generally considered, but quinary, the fifth member of each quincuncially arranged whorl being suppressed. As a rule Crucifers have in the adult condition bractless flowers; a few species have bracts normally; and they sometimes occur as abnormalities, and are then placed at the base of the peduncles, or emerge from the side of them, owing to imperfect detachment of bract and pedicel, and consequent uplifting or displacement in course of growth. *Subularia* has perigynous stamens springing from a cup-shaped receptacle. The fruits of *Morisia* and *Geococcus* ripen under ground. The long stamens of *Atelanthera* have 1-celled anthers. In *Streptanthus*, and some species of *Vella*, the long stamens are connate in pairs.

Distribution.—This large Order is very natural, and, as usually happens in such cases, the genera are very difficult to define. The species are most abundant in temperate and cold climates, and seldom found otherwise than on mountains in the tropics.

Qualities and Uses.—The general character is antiscorbutic, the watery juice being often pungent and occasionally acrid. The seeds yield oil, which is contained in their cotyledons. By cultivation the acrid juices become milder, and the structures are easily made very succulent, from abnormal development of parenchyma. Under these conditions they become valuable esculents, either in their roots, as the Turnip (*Brassica Rapa*), their stem and leaf-stalks, as Sea-kale (*Crambe maritima*), their stem, leaves, or undeveloped inflorescence, as Kohl-rabi, Cabbages, Greens, Kales, &c. in all their varieties, and Cauliflower and Broccoli, all apparently derived from *Brassica oleracea* by cultivation. *Brassica Napus*, Rape or Colza, is most valuable on account of the oil in its seeds, and its oil-cake as food for cattle. The Swede Turnip is supposed to be a hybrid between *B. campestris* and *B. Rapa* or *Napus*. Radishes (*Raphanus sativus*), Horse-radish (*Armoracia rusticana*), are cultivated on account of their pungency, as are also the herb and, still more, the seeds of the Mustards, *Sinapis alba* and *nigra*, the latter of which yields the proper table-mustard seed. Water-cress (*Nasturtium officinale*) and Garden-cress (*Lepidium sativum*) are pungent salad-plants. *Isatis tinctoria* and a Chinese species, *I. indigotica*, yield a blue dye from their silicles. Many of the Cruciferæ are remarkable for containing sulphur compounds, both in the seeds and in the herbage, whence the disagreeable smell of water in which they have been boiled, or even of the bruised fresh plant of some, as *Erysimum Alliaria*. Oil of Mustard, obtained by macerating the seeds of Black Mustard in water and distilling, is violently acrid. Many of the genera cited in the list above are represented by common wild plants in this country, the rest are found in most gardens; *Matthiola* is the Stock, *Cheiranthus Cheiri* the Wallflower, &c.

CAPPARIDACEÆ are herbs, shrubs, or rarely trees, with alternate simple or lobed exstipulate leaves; cruciform flowers; stamens numerous, or, if 6, not tetradynamous, on a disk, or with an internode separating them from the corolla, and a 1-celled pod or berry with 2 or more parietal placentas; seeds reniform, aperispermic.—Illustrative Genera: Tribe 1. CLEOMEÆ. Fruit capsular: *Cleome*, DC.; *Polanisia*, Raf. Tribe 2. CAPPAREÆ. Fruit baccate: *Cadaba*, Forsk.; *Capparis*, L.

Affinities, &c.—This Order is closely related to the Cruciferæ, both in structure and properties, being distinguished chiefly by the stamens, which are mostly indefinite, or which, when only six in number, are very rarely tetradynamous, and by the stipitate ovary. The parietal placentas and the disk ally them to the Resedaceæ, which likewise have kidney-shaped aperispermic seeds; there is a more distant affinity to the Bixaceæ, which have perispermic seeds. The development of the internodes between the circles of floral organs is a striking character in various Capparidaceæ: in *Cleome* and *Capparis* the thalamus has rather a discoid development below the stamens, the ovary being stalked; in *Gynandropsis* and *Cadaba* there is a stalk-like prolongation of the thalamus between the corolla and stamens and between the stamens and the ovary. This structure connects the plants in some degree with Passifloraceæ. In some species of *Mærua*, moreover, there is a "corona" like that of Passion-flowers. In other genera the receptacle is developed into a more or less fleshy or glandular disk. In *Physostemon* the stamens are curious, the two or four posterior ones having the filaments inflated or swollen below the anthers. Eichler describes the development of the andrœcium as showing that there are two whorls of stamens, each primarily consisting of two, first two lateral, then two antero-posterior tubercles, which subsequently subdivide into numerous filaments.

Distribution.—The species are somewhat numerous in the tropical subtropical regions of the world, especially in Africa.

Qualities and Uses.—There is great agreement with the Cruciferæ; but in some cases the pungent principles are dangerous. The Capers used as pickles are the flower-buds of various species of *Capparis* (*C. spinosa*, *Fontanesi*, *rupestris*, and *ægyptiaca*). The root of *Cratæva gynandra*, the Garlic Pear, is said to be very acrid and to blister like Cantharides. *C. excelsa* is a large tree in Madagascar. The *Polanisia icosandra* of the United States is used as a vermifuge; and the root of *Cadaba indica* is said to be aperient and anthelmintic. Many species have been introduced into our gardens: a few bear the open air in sheltered places.

RESEDACEÆ are herbs or undershrubs with unsymmetrical 4–8-merous small flowers, commonly with a fleshy one-sided hypogynous disk between the petals and the (3–40) stamens, which it supports. Pistil polycarpellary and 1-celled, or of several more or less distinct carpels. Pod 3- or 6-lobed, 3- or 6-horned, 1-celled with 3 or 6 parietal placentas, sometimes opening at the top before the aperispermic reniform seeds are ripe. Embryo curved.—Illustrative Genera: *Reseda*, *Oligomeris*.

Affinities, &c.—These plants agree in many respects with the Capparidaceæ, as in the presence of a disk supporting the stamens and the reniform seeds. By Müller they are placed between Capparids and Crucifers. There is a more distant relation to the Papaveraceæ, from which, however, they are always distinguished by their aperispermic seeds. Moringaceæ have many points in common, but differ in habit, foliage, straight embryo, and monadelphous stamens. The one-sided disk is an outgrowth from the thalamus. The petals of the Mignonette have a broad claw and a deeply divided or fringed limb. The pollen-grains are ellipsoid. The opening of the ovary before the seeds are ripe is worthy of note as an uncommon phenomenon; it is well seen in the Garden Mignonette (*Reseda odorata*).

Oligomeris is remarkable for the reduction of the parts of the flower, having but 2 petals and 3 stamens, and the disk is likewise absent. *Astrocarpus* has separate carpels.—A small order. Most of the kinds are European; but a few occur in India, South Africa, and in California. The best known plant of the Order is *Reseda odorata*, so much valued for its perfume and hardy character. *Reseda luteola*, a native weed, commonly called Weld, yields a yellow dye. Some of the species are acrid.

BIXACEÆ are shrubs or small trees with alternate, usually exstipulate, entire, leathery, often dotted leaves; regular hermaphrodite or unisexual flowers; sepals 2–7, slightly coherent below, imbricate; petals as many and distinct, or absent, sometimes very numerous; stamens hypogynous, generally indefinite; ovary sessile, or slightly stalked, 1- or rarely more-celled, with two or more parietal placentas; ovules curved; seeds numerous, with a straight or slightly curved embryo in the axis of fleshy perisperm; cotyledons broad; radicle next the hilum.—Illustrative Genera: *Bixa*, L.; *Oncoba*, Forsk.; *Flacourtia*, Commers.; *Erythrospermum*, Lam.

Affinities, &c.—Related to the Samydaceæ, but distinguished by their hypogynous stamens, and to the Passifloraceæ, but destitute of a coronet. From Capparids they differ in their perispermic seeds; from Cistaceæ in their straight embryo. Bentham and Hooker refer the small group Pangiaceæ here, while Baillon includes Papayaceæ, Lacistemaceæ, and Turneraceæ. The species are not very numerous, and are mostly natives of the hottest regions of the globe; some of the plants are bitter and astringent; the pulpy fruits of *Oncoba*, of *Flacourtia Ramontchia*, *sapida*, and *sepiaria* are edible. *Bixa Orellana* yields the substance called Annatto, used for colouring cheeses and as a dye; it is derived from a pulp surrounding the seeds.

CISTACEÆ are low shrubs or herbs with regular hermaphrodite flowers, persistent imbricate calyx, caducous crumpled petals, distinct hypogynous, mostly indefinite stamens; pod 1-celled, 3–5-valved, with as many parietal placentas; ovules straight; seeds perispermic; embryo curved or spiral, with the radicle remote from the hilum.—Illustrative Genera: *Cistus*, *Helianthemum*.

Affinities, &c.—Nearly related to Violaceæ, Bixaceæ, and Droseraceæ, but distinguished by the form and direction of the embryo; from the Hypericaceæ by the structure of the fruit and the absence of dots on the leaves, and from Linaceæ by the fruit; they also approach Papaveraceæ by *Dendromecon*: and Lindley considers that there is some connexion with Capparidaceæ and Cruciferæ; but the 4-merous plan and aperispermic seeds of these Orders remove them widely. Some of the *Helianthema* have dimorphic flowers. The pollen is ellipsoid. *Lechea* has stamens fewer than the petals. The Cistaceæ are most abundant in South Europe and North Africa, but occur in other parts of the globe. The gum-resin called Ladanum is obtained from *Cistus creticus*, *ladaniferus*, *Ledon*, and others; and the plants generally are regarded as resinous and balsamic. Many species are cultivated for their beautiful but fugacious flowers. *Helianthemum vulgare*, a native plant, is remarkable for the irritability of the stamens in the newly opened flowers.

DROSERACEÆ are bog-herbs, mostly glandular-haired, with regular hermaphrodite 5-merous flowers and marcescent calyx and corolla; stamens as many as the petals, or indefinite, hypogynous or perigynous; the anthers fixed by the middle, extrorse; ovary free, 1-celled; ovules numerous, inverted; styles as many as the placentas or connate: pod 1-celled, placentas parietal or basilar; the embryo minute, at the base of fleshy perisperm.—Illustrative Genera: *Drosera*, L.; *Aldrovanda*, Monti; *Dionæa*, Ellis.

Affinities, &c.—The interesting but not very numerous plants of this Order are remarkable for the circinate curvature of their flower-stalks, which, together with the absence of stipules, the extrorse anthers, divided styles, &c., separates them from the Violaceæ, which they approach; they are connected with Hypericaceæ by *Parnassia*, and have some affinity to Cistaceæ and Turneraceæ. Bentham and Hooker place them near the Saxifrages. These plants are found in bogs or marshes in most parts of the globe, excepting the Arctic regions. Their most interesting characters reside in the leaves, which in *Drosera* (Sun-dews) are covered with beautiful glandular hairs, which have a spiral vessel running up their stalks and secrete a digestive fluid. They are also endowed with the power of motion when touched, so that an insect alighting on the leaf is unable to make its escape owing to the viscid fluid exuded from the glands. The hairs then bend over the insect, which becomes dissolved by the acid fluid, and ultimately absorbed. *Aldrovanda vesiculosa*, a native of South Europe, has curious whorled, cellular, spoon-shaped leaves. *Dionæa muscipula*, the Venus's Fly-trap of the North-American bogs (occasionally cultivated in stoves here), is well known for the remarkable irritability and digestive properties of the lamina of the leaf, the two lobes of which close upon any object touching the upper face. The Droseraceæ are said to be acrid.

VIOLACEÆ. The Violet Order.

Coh. Parietales, *Benth. et Hook.*

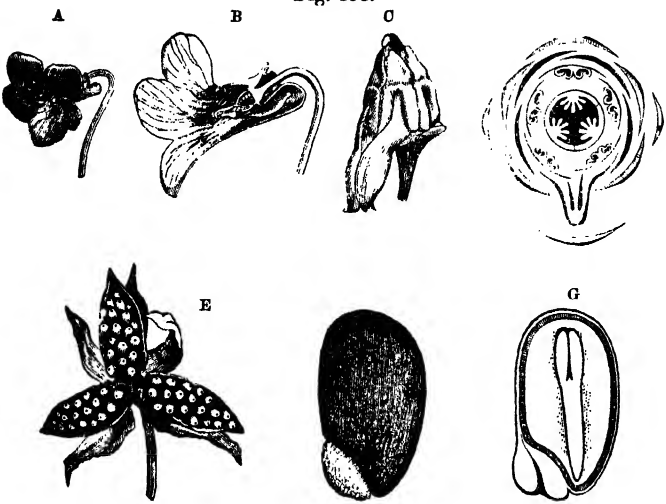
Diagnosis.—Herbs or shrubs: leaves alternate, usually stipulate; flowers regular or irregular, hermaphrodite, with a somewhat irregular, generally 1-spurred corolla of 5 petals: stamens 5, hypogynous, with adnate introrse anthers connivent over the pistil, connective of the anther usually prolonged; style and stigma single; pod 1-celled; 3-valved, with 3 parietal placentas in the middle of the valves; seeds perispermic; embryo straight.

Character.

Thalamus flat or slightly rounded. *Calyx*: *sepals* 5, persistent, usually elongated at the back, imbricated in æstivation. *Corolla*: *petals* 5, hypogynous, equal or unequal, one usually spurred, withering-persistent; obliquely convolute in æstivation. *Stamens* 5, alternate with the petals, or occasionally opposite, inserted on an hypogynous disk, often unequal; *anthers* 2-celled, introrse, separate or cohering, and

lying upon the pistil; the filament or connective prolonged beyond the lobes of the anthers, in the irregular flowers two of the filaments are spurred at the base. *Ovary* compound, 1-celled,

Fig. 353.



A. Flower of Violet. B. Section of same. C. Andrœcium. D. Plan of flower, with bract and two bractlets, &c. E. Capsule open, to show parietal placentation. F Seed with aril, much enlarged. G. Seed with straight embryo in perisperm.

with numerous ovules on 3 parietal placentas opposite the 3 outermost sepals, or rarely 1-ovuled; *ovules* anatropous; *style* single, mostly declinate; *stigma* capitate, oblique, hooded. *Fruit*: a capsule bursting into three valves, with the placentas up the middle; *seeds* mostly numerous, often arillate; *embryo* straight in the axis of fleshy perisperm.—Illustrative Genera: *Viola*, L.; *Papayrola*, Aubl.; *Alsodeia*, Thouars.

Affinities, &c.—The typical formula is $S5\ P5\ A5\ \widehat{G3}$. By the irregular flowers and appendaged anthers we readily distinguish most of the Violaceæ from the Droseraceæ, Cistaceæ, and Sauvagesiaceæ; and in *Alsodeia* and other genera, where the calyx and corolla are regular, the simple style and capitate stigma are still available; and several other important differences exist, such as:—the definite number of stamens and straight embryo, unlike that of the Cistaceæ; different vernation and stipulate condition of the leaves, unlike Droseraceæ; while Sauvagesiaceæ, besides having the anthers unappendaged, have either numerous stamens, or, if five, they are opposite to the

petals and alternate with five scales; moreover the capsule bursts septicidally, so that the placentas are at the edges of the valves. Violaceæ are related more distantly to Passifloraceæ. In the native species of the genus *Viola*, it is not uncommon so find apetalous flowers, especially in the autumn. The pollen-grains are ellipsoid or prismatic.

Distribution.—An Order consisting of a few genera, some, such as *Viola* and *Alsodeia*, rich in species, the greater number with but few. The irregular Violaceæ belong chiefly to Europe, North Asia, and North America, where they are generally small herbs, and to South America, where they are mostly shrubby; the regular genera, *Alsodeia* &c., belong to South America, Africa, and Malacca.

Qualities and Uses.—The Order is characterized in general by emetic properties, which are especially developed in the South-American *Ionidia*; *I. parviflorum, I. Poaya, I. Ituba*, are used there instead of Ipecacuanha, and the last was formerly supposed to be the true Ipecacuanha-plant. *Viola canina*, the common Dog-violet of our hedges, is said to be beneficial in skin diseases; and the same properties are attributed to *Anchietia salutaris* in Brazil, where it is also used as a purgative. The roots of the Sweet Violet, *V. odorata*, are emetic and purgative; its seeds are also purgative. *V. tricolor* is the Pansy or Heart's-ease; its leaves have been supposed to contain hydrocyanic acid, since they smell like peach-blossom when bruised.

The SAUVAGESIACEÆ form a small group sometimes separated from Violaceæ on account of the characters mentioned above. They are related to the Hypericaceæ through *Parnassia*.

IACEÆ constitute a small and unimportant Order bearing very close affinity to the tribe Sileneæ of the Order Caryophyllaceæ in the floral envelopes and stamens; but the placentas are parietal, and the embryo is straight, which causes them to approach Violaceæ, and especially Sauvagesiaceæ, from which, however, they differ in their united sepals and extrorse anthers. Most of the plants are found in South Europe and North Africa; but a few species are scattered in other parts of the world. They are said to be mucilaginous and aromatic.—Illustrative Genus: *Frankenia*, L.

TAMARICACEÆ are shrubs or herbs of fastigiate growth, with alternate scale-like leaves, usually pitted; flowers in close spikes or racemes; calyx 4–5-parted, persistent; petals distinct, springing from an hypogynous disk, equalling the petals or twice as many, distinct or coherent; ovary superior, ovules numerous, ascending; capsule 3-valved, 1-celled, with 3 placentas either at the base or 1 in the middle of each valve; seeds comose or winged, without perisperm; embryo straight; radicle inferior.—Illustrative Genus: *Tamarix*, L.

Affinities, &c.—Endlicher looked upon this Order as intermediate between Hypericaceæ (through Reaumuriaceæ) and Lythraceæ, while Lindley thought it stood rather between Violaceæ and Crassulaceæ, and De Candolle placed it near Portulacaceæ, as also do Bentham and Hooker, who include in it *Reaumurieæ* and *Fouqueria*. From all the above, however, it differs in the nature of the seeds.

group consisting of two genera, one with several, the other with very few species. The plants are natives of the northern hemisphere of the Old World, growing chiefly by the sea-shore, or on the margins of rivers or lakes.

Qualities and Uses.—The bark is bitter and astringent; and those kinds growing near the sea yield abundance of soda when burnt. *Tamarix mannifera* yields the Manna of Mount Sinai, a kind of mucilaginous sugar, said to be exuded in consequence of the attacks of a Coccus-insect. Several species are attacked by gall-insects; and the galls of *T. indica, dioica, Furas,* and *orientalis* are used in medicine and for dyeing. *Tamarix gallica* flourishes well near the sea on our coasts, and is an ornamental shrub. *Myricaria germanica* is a handsome shrub in our gardens.

CARYOPHYLLACEÆ. THE PINK ORDER.

Coh. Caryophyllinæ, *Benth. et Hook.*

Diagnosis.—Herbs with opposite entire leaves; stems swollen at the joints; flowers symmetrical, 4–5-merous, with or without petals; stamens distinct, not more than twice as many as the sepals, hypogynous or perigynous; styles 2–5; seeds attached to the base or to the central placenta of the 1-celled (rarely 3–5-celled) capsule; embryo curved round the mealy perisperm.

Thalamus flat. *Calyx*: *sepals* 4 or 5, persistent, distinct or coherent into a tube. *Corolla*: *petals* 4 or 5, clawed, often deeply

Fig. 356.

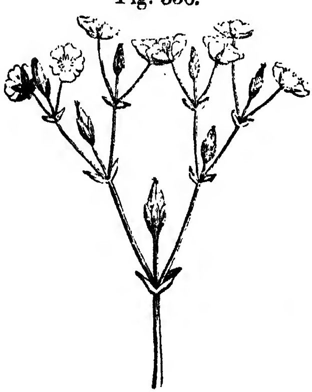


Fig. 354.

Fig. 357.

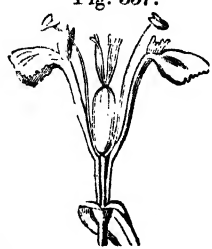


Fig. 355.

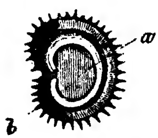


Fig. 354. Capsule of *Cerastium*, burst.
Fig. 355. Section of seed of *Lychnis*: *a*, endosperm; *b*, embryo.
Fig. 356. Dichasial cyme of *Cerastium*.
Fig. 357. Section of a flower of *Silene*, with an internode between the calyx and corolla.

bifid, sometimes wanting, mostly separated by a short internode from the calyx. *Stamens* twice as many as the petals, or equal to and opposite to the sepals, sometimes fewer, inserted with the petals; *filaments* awl-shaped, sometimes coherent; *anthers* innate. *Ovary* sessile, or raised with the corolla and stamens on a short stalk above the calyx, 1-celled, with a central placenta or with 2–5 dissepiments extending to the centre; *ovules* few or numerous; *stigmas* 2–5, filiform, resembling the styles, but papillose down the inner side. *Fruit* capsular, 1-celled, with a central placenta, 2–5-valved, or splitting into 4–10 teeth above (fig. 354), or 2–5-celled, loculicidally dehiscent, with the placentas adhering to the septa; *seeds* mostly indefinite; the *embryo* mostly curved round the perisperm (fig. 355), rarely straight or spiral, with little perisperm; radicle next the hilum.

ILLUSTRATIVE GENERA.

Tribe 1. ALSINEÆ. *Sepals distinct.*	Tribe 2. SILENEÆ. *Sepals cohering into a tube.*
Sagina, *L.*	Dianthus, *L.*
Alsine, *Wahlenb.*	Saponaria, *L.*
Arenaria, *L.*	Silene, *L.*
Stellaria, *L.*	Lychnis, *L.*
Cerastium, *L.*	

Affinities, &c.—The typical floral formula is $S\,5\ P\,5\ A\,5+5\ \overset{\frown}{G\,5}$. The opposite entire leaves springing from thickened nodes, definite stamens, and the character of the placenta and seeds serve to distinguish the great majority of this well-marked Order. The nearest relations of the Caryophyllaceæ, as here defined, are unquestionably the Illecebraceæ and Portulacaceæ, which we separate more for the sake of convenience of distinction than on account of natural diversity, since in both those Orders there is a variation between the hypogynous and perigynous conditions. The Illecebraceæ may be distinguished by their scarious stipules and utricular fruit, and the Portulacaceæ by the 2-leaved calyx and by the stamens when equal to the sepals being alternate, or opposite to the petals, since it seems more convenient to keep the *Mollugineæ* with Portulacaceæ if they are divided. The apetalous forms, and the alliance with the Orders just named, connect this Order with the Amarantaceæ and Chenopodiaceæ and several other families, all characterized by a curved embryo surrounding a floury perisperm.

The placentation of the Caryophyllaceæ is regarded by some authors as forming one of the exceptions to the marginal type, the free central column in mature ovaries being regarded as a product of the receptacle, independent of the carpels. But the dissepiments exist in the early stages of development, and are torn away during the expansion of the ovary: hence there is no necessity to assume the independent origin of the placentas. Monstrous blossoms of plants of this Order do not decide the question, since these have been found with really independent growth of the ovules from the base of the ovary, and with ovules developed upon the margins of the carpels. *Lychnis* and some other genera have petals with a scale-like outgrowth. Several species are diœcious.

Distribution.—An Order consisting of several genera and a large number of species, for the most part natives of temperate and cold climates, extending to the Arctic regions and to almost the extreme limit attained by flowering plants on mountains.

Qualities and Uses.—The plants of this Order are generally devoid of active properties—some of them containing more or less of a deleterious principle, called *saponine*, as *Saponaria*, *Agrostemma*, *Silene*, &c.; and *Gypsophila Struthium*, the Egyptian Soap-root, derives its name from its saponaceous properties; this substance is generally most abundant in the roots. The genus *Dianthus*, or Pink, is remarkable for the beauty of its flowers; *D. barbatus* is the Sweet William; *D. plumarius* is the parent of the varieties of Garden Pink; *D. Caryophyllus* (the Clove-Pink) of the Carnation and its varieties. *Lychnis* and *Silene* also afford handsome garden plants. A large proportion of the Plants of this Order are insignificant weeds.

MALVACEÆ. THE MALLOW ORDER.

Coh. Malvales, *Benth. et Hook.*

Diagnosis.—Herbs or shrubs with alternate stipulate leaves often covered with soft down and regular flowers; calyx valvate, and

Fig. 358.

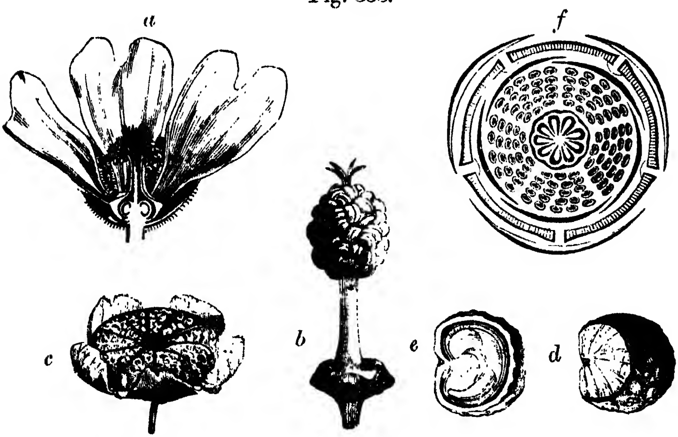


Fig. 358. *a*, flower of Mallow, longitudinal section; *b*, andrœcium; *c*, calyx and fruit; *d*, carpel detached; *e*, carpel cut open to show embryo; *f*, diagram of flower, with three bracteoles, five sepals, five petals, five compound stamens, and ten carpels.

corolla convolute in æstivation; stamens numerous, monadelphous in a tube which is adherent below to the short claws of the petals; anthers ultimately 1-celled, or always 2-celled.

Character.

Thalamus flat or rounded. *Calyx*: *sepals* 5, rarely 3 or 4, more or less united below, valvate in the bud, often surrounded by an epicalyx. *Corolla*: *petals* equal in number to the sepals, hypogynous, contorted in æstivation, free or adherent to the tube of the stamens. *Stamens* indefinite, monadelphous, hypogynous, all perfect; *anthers* 1–2-celled. *Ovary*: *carpels* several, each forming a cell around a central axis, either coherent into a multilocular compound ovary, or distinct; *ovules* definite or indefinite, on the ventral suture; *styles* equal in number to the carpels or twice as many; coherent or distinct; *stigmas* various. *Fruit*: a several-celled capsule, or a collection of separating indehiscent cocci or of follicles, the carpels 1- or many seeded; *seeds* with little or no perisperm, *embryo* curved, cotyledons much twisted, oily, testa sometimes hairy.

ILLUSTRATIVE GENERA.

A. *Andrœcium tubular; tube entire or but slightly divided at the apex.*

Tribe 1. MALVEÆ. *Herbs or undershrubs. Staminal column antheriferous to the top; styles as numerous as the cells of the ovary; ripe carpels seceding from the columella.*

Malope, *L.*
Althæa, *L.*
Malva, *L.*
Sida, *L.*

Tribe 2. URENEÆ. *Herbs. Staminal column destitute of anthers at the top; styles twice as many as the cells of the ovary; fruit as in* Tribe 1.

Pavonia, *L.*
Urena, *L.*

Tribe 3. HIBISCEÆ. *Herbs or undershrubs. Styles as many as the carpels; fruit syncarpous, capsular.*

Hibiscus, *L.*
Gossypium, *L.*

B. *Andrœcium tubular at the base only, or divided throughout into filaments.*

Tribe 4. BOMBACEÆ. *Large trees or shrubs. Staminal column divided into 5 or more divisions, each with one or more anthers; styles confluent or equal to the carpels; fruit syncarpous, dehiscent or indehiscent.*

Adansonia, *L.*
bax, *L.*
Durio, *L.*

Affinities, &c.—The "compound" stamens of these plants appear first in the form of five little tubercles, the primordial stamens; from the sides of these are subsequently developed others. The anthers are bilocular in the first instance, but become 1-celled by the obliteration of the partitions. Where the stamens are superposed to the petals it is probable that the latter are not autonomous organs, but outgrowths from the stamens. The typical formula may be thus written, $S\,5\ P\,5\ \underset{\times}{\overset{\frown}{A\,5}}\ G\,5$, variations being dependent on cohesion, adhesion, multiplication, &c. Malvaceæ are closely allied to Sterculiaceæ and Tiliaceæ (especially to the first, which, indeed, are only kept separate for convenience' sake) by the general structure and the æstivation of the calyx, but are distinguished by their 1-celled anthers; to the Geraniaceæ they are related by the monadelphous

stamens, twisted æstivation of the corolla, and the occasional separation of the carpels from a central axis in the ripe fruit; with Chlænaceæ there is a connexion through the epicalyx or calycine involucre and the monadelphous stamens; and some points of structure, but especially the properties, resemble those of Linaceæ: from Camelliaceæ, which have the stamens more or less coherent, they may be distinguished by the valvate calyx. *Malope* presents a curious condition of the carpels, which are numerous and distinct, resembling those of a Ranunculaceous plant. *Malvaviscus* has succulent fruit. The epicalyx is probably of stipular nature. The Bombaceous subdivision is referred here on account of the 1-celled anthers. The trunks of some of the trees in this group attain enormous age and dimensions, as in the *Adansonia* or Baobab, and the *Bombax*, the latter of which produce great projecting buttresses from their stems. The calyx in this subdivision is tough and leathery; and the pollen is generally smooth, not spiny as in the rest of the family. The hairy seeds of this subdivision recall those of *Gossypium*. The *Durio* group of the tribe Bombaceæ are clothed with large peltate scales. In *Boschia* the anthers are ovoid and open by a terminal pore.

Distribution.—A large order with several genera and very numerous species; the latter are most abundant in the tropics, diminishing gradually in the temperate regions, and absent from the frigid zone.

Qualities and Uses.—The ordinary properties of this Order depend on the abundance of a bland mucilage, especially in the roots, as in the Marsh-mallow (the French *Guimauve*) (*Althæa officinalis*), the flower of the Hollyhock (*Althæa rosea*), the common Mallow (*Malva sylvestris*), &c. The leaves of the Hollyhock yield a blue dye like indigo. *Hibiscus esculentus* furnishes okro or gombo pods, used in soups and as demulcents. But the most important qualities of these plants depend upon their tissues, namely the fibrous liber of their stems, which in some cases furnishes large quantities of hemp-like fibre to commerce, as the *Hibiscus cannabinus* (Sun-hemp), *H. arboreus*, various species of *Sida*, &c., and the hairs of the seeds of *Gossypium*, constituting Cotton. Four distinct species of Cotton are supposed to exist, viz.:—*G. herbaceum*, the ordinary Indian Cotton-plant, probably a cultivated variety of *G. Stocksii*, which is wild in Sindh; *G. arboreum*, the Indian Tree-cotton; *G. barbadense*, to which the North-American Cottons and the Bourbon cotton of India belong; and *G. peruvianum* or *acuminatum*, Pernambuco or Brazil cotton. The seeds of *Gossypium* contain a large quantity of almost colourless oil, together with a brown resinous substance contained in special reservoirs, which colours the expressed oil. The hairs of the seeds of the Silk-cotton trees (*Bombax*) cannot be spun like cotton, but are used for stuffing cushions, &c. The Durian (*Durio zibethinus*) has an aromatic edible fruit. The fruit of the Baobab (*Adansonia*), gigantic African and Australian trees, has an agreeable acid juice. Most of the Malvaceæ have handsome flowers, and many are cultivated in our gardens and stoves.

STERCULIACEÆ. The Sterculia Order.

Coh. Malvales, *Benth. et Hook.*

Diagnosis.—Herbs, trees, or shrubs, sometimes climbing, with alternate simple or compound leaves and free deciduous stipules; flowers regular

or irregular, frequently unisexual by abortion; calyx and corolla resembling those of Malvaceæ or petals absent; andrœcium columnar or tubular, or rarely stamens few, free; anthers 2-celled and extrorse, in heads or rings or dispersed, with or without intervening staminodes; carpels 5, rarely 3 or solitary, distinct or coherent, often pedicellate; fruit and seeds very variable.

ILLUSTRATIVE GENERA.

Tribe 1. STERCULIEÆ. *Flowers and unisexual by abortion; anthers clustered or annular.*

Heritiera, *Ait.*
Sterculia, *L.*
Cola, *Schott.*

Tribe 2. HELICTEREÆ. *Flowers perfect; petals deciduous. Andrœcium columnar below, cup-shaped above: staminodes on the margins of the cup, alternating with the anthers.*

Helicteres, *L.*

Tribe 3. ERIOLÆNIEÆ. *Flowers hermaphrodite; petals deciduous. Andrœcium tubular, conical, antheriferous for nearly its whole length.*

Eriolæna, *DC.*

Tribe 4. FREMONTIEÆ. *Flowers hermaphrodite: stamens conjoined; anthers 5; staminodes wanting.*

Fremontia, *Hook.*
Cheirostemon, *L.*

Tribe 5. DOMBEYEÆ. *Flowers hermaphrodite: petals flat, persistent. Andrœcium tubular, antheriferous at the margin; anthers solitary or in groups, alternating with staminodes.*

Dombeya, *Cav.*
Melhania, *Forsk.*

Tribe 6. HERMANNIEÆ. *Flowers hermaphrodite: petals persistent, æstivation. Andrœcium tubular at the base only; staminodes wanting.*

Hermannia, *L.*
Waltheria, *L.*

Tribe 7. BUETTNERIEÆ. *Petals concave at the base: andrœcium tubular; anthers marginal, solitary, or in groups between the staminodes.*

Buettneria, *L.*
Abroma, *Jacq.*
Leptonychia, *Turcz.*

Tribe 8. LASIOPETALÆ. *Flowers hermaphrodite; petals 0 or scale-like or lanceolate. Andrœcium tubular below, bearing above five anthers and as many staminodes, the latter opposite the sepals or wanting.*

Thomasia, *Gay.*
Lasiopetalum, *Smith.*

Affinities, &c.—The usually 2-celled anthers separate the plants of this Order from the Malvaceæ, the monadelphous condition from the Tiliaceæ. Nevertheless the distinction between this Order and Malvaceæ is purely artificial, and is here retained for convenience' sake only.

Many plants of this Order are interesting in structural respects. *Delabechea* (Australia), *Brachychiton*, and others have a trunk swollen midway between the ground and the crown of the tree, giving the appearance of a huge flask or bottle. *Helicteres* is so called from its twisted follicles; the pods of some *Sterculieæ* open out like leathery leaves with the ripe seeds on their margins. The species of *Sterculia* and *Cola* are remarkable for the variable condition of their seed, some having perisperm, others not; the direction of the radicle with reference to the hilum is also different in different species. *Cola* has often three or four cotyledons, or perhaps two, deeply divided. The pollen is ovoid with three plaits, or globose or polygonal, not muricate except in *Dombeyeæ*.

Distribution.—An Order the species of which are mostly tropical and subtropical.

Qualities and Uses.—Mucilaginous. *Sterculia Tragacantha* yields the gum Tragacanth of Sierra Leone, *S. urens* a similar gum; the seeds of all the species are oily, like those of Malvaceæ; the same properties are generally diffused. *Sterculia guttata* and *villosa* and species of other genera yield fibres fit for cordage and woven fabrics. *Cola acuminata* furnishes the Cola nuts, greatly esteemed by the negroes for their bitter restorative properties. *Cheirostemon platanoides*, the Hand-plant of Mexico, has a remarkable-looking flower: the tube of the monadelphous stamens is split above and spread out, so that the anthers resemble five fingers or claws, while the curved style looks like a thumb. This and various other plants of the Order have been introduced as stove-shrubs. The seeds of *Theobroma cacao* and other species furnish the Cocoa of commerce.

TILIACEÆ. THE LIME OR LINDEN ORDER.

Coh. Malvales, *Benth. et Hook.*

Diagnosis.—Trees (rarely herbs) with alternate usually stipulate leaves; flowers regular, hermaphrodite or unisexual; calyx valvate; petals imbricated in æstivation; sepals deciduous; stamens numerous, free, or polyadelphous; anthers 2-celled; ovary free, 2–∞-celled; embryo curved; cotyledons leafy.—Illustrative Genera: *Luhea*, Willd.; *Corchorus*, L.; *Triumfetta*, Plum.; *Tilia*, L.; *Grewia*, Juss.; *Elæocarpus*, L.

Affinities, &c.—The distinct or polyadelphous stamens, the 2-celled anthers, and the disk separate these plants from their near allies, the Malvaceæ and Sterculiaceæ. From Camelliaceæ they differ in the æstivation of the calyx, and from Bixaceæ in the structure of the fruit. Various remarkable peculiarities of structure occur in the genera. Some species of *Apeiba* are said to have 24 cells in the fruit; *Diplophractum* has parietal placentas with spurious dissepiments in the fruit. The polyadelphous stamens of *Luhea*, and of the American species of *Tilia*, which stand in bundles before the petals, are supposed to be instances of *chorisis*; but the petal in these cases is probably an outgrowth from the staminal tubercle. Limes are peculiar in the adhesion of the flower-stalk to the bract. *Grewia* has glandular petals; *Elæocarpus* has them fringed; in some species they are absent.

Distribution.—There are between three and four hundred species, pertaining to thirty-five or forty genera. The Limes or Lindens (*Tilia*) are trees of the northern parts of both hemispheres; but the rest of the Order are chiefly tropical. *Triumfettas* are tropical weeds with bur-like fruits.

Qualities and Uses.—The general properties are the same as those of the allied Orders—mucilaginous juices and fibrous bark. Many are valuable timber-trees, and some yield edible fruits. The fibrous liber of the European *Tiliæ* furnishes the well-known Russian "bast" or "bass;" various species of *Corchorus* furnish fibres in India, especially *C. capsularis*, which affords "Jute," a fibre very extensively substituted for hemp; *C. olitorius* is used as a pot-herb. The berries of *Grewia sapida, asiatica*, and others are pleasantly acid, and are used in making sherbet; and the

berries of some kinds of *Corchorus* and of *Elæocarpus* are eaten. The seeds of *Elæocarpus* are used as beads, and *E. Hinau* yields a dye. Various species of *Luhea* (Brazil) and *Grewia* (East Indies) furnish valuable timber. The Lime-trees of Europe (*Tilia europæa*, *grandifolia*, and *parvifolia*) are valued not only for their *bast*, but for their beauty, their white even wood, and the fragrance of their blossoms. Many of the tropical species, such as *Sparmannia africana*, *Glyphæa grewioides*, have been introduced as stove-shrubs. *Honckenya ficifolia* has large violet flowers.

DIPTERACEÆ are large trees abounding in resinous juice, with alternate strongly feather-ribbed leaves and large convolute deciduous stipules; flowers perfect, the calyx 5-lobed, lobes imbricate, unequal, persistent, afterwards often enlarged like wings; petals 5, hypogynous; stamens hypogynous, indefinite, distinct, or slightly and irregularly polyadelphous; anthers subulate, connective often produced above; ovary superior, 3-celled; fruit 1-celled by suppression, 1-seeded, and 3-valved or indehiscent, and surrounded by the enlarged calyx, forming a crown above it; seeds aperispermic. — Illustrative Genera: *Dipterocarpus*, Gærtn.; *Dryobalanops*, Gærtn.; *Vateria*, L.; *Shorea*, Roxb.

Affinities, &c.—Tropical trees related to the preceding Orders in some respects, but in the imbricated calyx and in other particulars having more affinity to the Clusiaceæ, from which they differ in the æstivation of the corolla and in the presence of stipules. Their large deciduous stipules resemble those of *Magnolia*; but the most characteristic feature of the Order is the enlarged persistent calyx, which forms long winged lobes crowning the fruit. Some authors separate *Lophira* as the type of a distinct Order, which is in some degree (as in its 1-celled ovary) different both from the Dipteraceæ and the Clusiaceæ, but may probably remain among the former. *Ancistrocladus* is a climber.

Distribution.—This Order consists of ten or twelve genera, comprising upwards of a hundred species. These plants are large trees or rarely climbing shrubs of the forests of tropical Asia. *Lophira* belongs to Sierra Leone.

Qualities and Uses.—Fine timber-trees whose juices yield a balsamic resin, of which various kinds are imported. Sumatran hard Camphor is found in the form of concretions in fissures and cavities of the trunk of *Dryobalanops Camphora*; the Camphor-oil of Borneo and Sumatra is said to be the same substance in a fresher state. *Shorea robusta* yields the Dhoona or Dammar pitch, used for incense in India. *Vateria indica* affords the Piney resin or Piney Dammar of India, sometimes called Indian Copal or gum Animi, largely used for making varnish. *Dipterocarpus trinervis* and other species yield a balsam like Copaiba, sometimes called Gurjun balsam or wood-oil. *Lophira* is called the Scrubby Oak in Sierra Leone; its dry corky bark contains no resinous juice.

CHLÆNACEÆ constitute a small and little-known Order, consisting at present of a few shrubs, natives of Madagascar; related to Malvaceæ in having monadelphous stamens and an epicalyx; but the calyx is imbricated in æstivation, like that of Camelliaceæ &c. Placed by Lindley near Oxalidaceæ, Balsaminaceæ, Linaceæ, and Geraniaceæ, by Bentham and Hooker near Dipterocarps.

TERNSTRŒMIACEÆ OR CAMELLIACEÆ.

The Camelia Order.

Coh. Guttiferales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs, with alternate, rarely opposite, simple, rarely compound leaves and no stipules; flowers regular, rarely unisexual; andrœcium polyandrous, hypogynous; sepals and petals both imbricated in æstivation; stamens more or less coherent (1-, 3-, or 5-adelphous) at the base, and adherent to the bases of the petals; anthers 2-celled; seeds few, sometimes arillate; perisperm little or none; embryo straight or folded, with the cotyledons large and thin, oily.—Illustrative Genera: Tribe 1. Rhizoboleæ. *Caryocar*, L.: Tribe 2. Marcgraavieæ. *Marcgraavia*, L.; Tribe 3. Ternstrœmieæ. *Ternstrœmia*, L. f.; Tribe 4. Saurauieæ. *Sauraujа*, Willd.; Tribe 5. Gordonieæ. *Gordonia*, Ellis, *Camellia*, Linn.; Tribe 6. Bonnettiæ. *Kielmeyera*, Mart.

Affinities, &c.—Ternstrœmiads differ from Bixads in their many-celled ovary and want of stipules; from Dipterocarps in their calyx, which is not accrescent, their many-celled ovary, and watery (not resinous) juice. From *Tiliaceæ* they differ in their imbricate (not valvate) calyx; from Guttifers in their alternate leaves, usually perfect flowers, long style, curved embryo, &c. From Hypericads they differ in habit, foliage, and inflorescence. Through *Sauraujа* they are connected with the Ericaceous genus *Clethra* and with Dilleniads. *Eurya* establishes a connexion with *Sapotaceæ*; but these latter plants have extrorse anthers. The tribe *Marcgraavieæ*, by some considered a distinct Order, comprises a few plants differing from the rest of the Order in their aggregate flowers, introrse, basifixed anthers, sessile stigmas, and specially in their very peculiar horn-line tubular bracts. The *Rhizoboleæ* are large trees, with opposite digitate leathery leaves, with an articulated stalk, and no stipules; sepals 5 or 6, more or less coherent, imbricated; petals 5–8, inserted with the numerous stamens on an hypogynous disk; stamens slightly coherent, in two circles, the inner shorter and often abortive; ovary superior, 4–5- or many-celled, with as many short styles and minute stigmas, each cell with 1 ovule attached in the axis; fruit of several combined indehiscent 1-seeded nuts, with a large aperispermic seed chiefly consisting of an enormous tigellum with the cotyledons lying in a groove. The large palmate leaves of *Caryocar* resemble those of *Æsculus*; but here the caulicle, and not the cotyledons, forms the mass of the embryo.

Distribution.—The Ternstrœmiads constitute a rather large family, distributed mainly in tropical America and Eastern Asia; very few are found in North America, and one species in the Canaries.

Qualities and Uses.—Some *Saurauјas* possess emollient properties. *Gordonia* is astringent. Tea is the produce of *Thea chinensis*; black tea and green tea are produced by the same plant, the difference consisting in the time of picking and mode of preparation of the leaves. The stimulant properties of tea are due to the presence of a volatile oil and an astringent principle; the nutritive qualities to a nitrogenous substance called theine. The leaves also contain caseine, which, being insoluble in water,

is not utilized by us; but it is stated that the Tibetans, after drinking the infusion, mix the leaves with fat and then eat them. Assam tea is the produce of a species, *T. Assamica*, a native of the country whence its name is derived. *Camellia Sasanqua* is used with *Olea fragrans* to give flavour and perfume to Chinese tea; *C. oleifera* affords excellent salad-oil. *Frezia theoides* is made into tea in Panama. The Marcgraavias have diuretic properties. The Souari nuts of commerce are the separated fruit-lobes of *Caryocar butyrosum*, so called on account of the oil in the seeds. The timber of this tree is highly valued. Many of the plants of this Order are in cultivation on account of their handsome flowers, such as the *Camellia, Gordonia, Stuartia,* &c.

CLUSIACEÆ OR GUTTIFERÆ. THE GAMBOGE ORDER.

Coh. Guttiferales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs, occasionally parasitical, with resinous juice; opposite, coriaceous, exstipulate, entire leaves; flowers axillary or terminal, perfect or diclinous by abortion; sepals imbricated or in 2 or more decussating pairs, usually persistent and petaloid; petals hypogynous, isomerous with the sepals, sometimes confounded with them; stamens hypogynous, numerous, distinct, or in several parcels, rarely definite, filaments of various lengths; anthers adnate, not beaked, sometimes 1-celled, opening by a pore or transverse slit; disk fleshy, sometimes 5-lobed; ovary superior, 1- or many-celled; stigmas sessile, peltate, or radiate; ovules solitary or few on axile placentas; seeds frequently with an aril, without perisperm. Embryo large; cotyledons minute, fused together or indistinguishable.—Illustrative Genera: *Clusia*, L.; *Garcinia*, L.; *Xanthochymus*, Roxb.; *Cambogia*, L.; *Calophyllum*, L.

Affinities, &c.—This Order is related to the Hypericaceæ in many respects, but may be distinguished by the tree-like habit, the leathery leaves with articulated stalks, the tendency to a binary arrangement of the floral envelopes, the seeds usually solitary in the cells of the ovary, &c. The genera with 5-merous flowers, *Arrudea, Moronobœa,* &c., form a connecting link. The relationship to Ternstrœmiads has been alluded to under that family. The *Clusiæ* are described as parasitical, overgrowing other trees and killing them; perhaps, however, they are merely epiphytic, like *Ficus*.

Distribution.—The genera are about twenty-five in number, comprising some two hundred and fifty species, distributed throughout the tropics, chiefly in South America, but some in Africa.

Qualities and Uses.—An acrid juice, forming a yellow gum-resin, with purgative properties, is one of the most striking characteristics of this Order. The various kinds of Gamboge are the most familiar examples of this substance, and are derived from various species of *Garcinia*. Siam gamboge is yielded by *Garcinia Morella*, var. *β. pedicellata*. Ceylon gamboge is said to be derived from *Garcinia Morella*, the form with sessile flowers; the Pipe-gamboge of Siam from *G. pictoria*; Coorg gamboge is

also from a *Garcinia*; *G. elliptica* furnishes the gamboge of Sylhet. The species of *Clusia* yield a useful resinous juice, as do those of *Calophyllum*, *C. Calaba* furnishing the East-Indian resin called Tacamahaca. *Pentadesma butyracea*, the Butter- or Tallow-tree of Sierra Leone, is so named from the yellow fatty substance which exudes from the cut fruit. Kokum butter, or *Oleum Garciniæ*, is a fatty substance extracted from the seeds of *Garcinia indica*. Although the resinous juices are usually so active in their properties, the fruits of various Clusiaceæ are not only edible, but highly prized for their delicious flavour. The Mammee Apple, or Wild Apricot of South America, is the fruit of *Mammea africana*; the juice of the flowers is fermented and distilled, and the sap is made into a kind of wine. The celebrated Mangosteen is the fruit of *Garcinia Mangostana* (native of Malacca); other species of *Garcinia*, as *G. pedunculata*, *cornea*, &c., have edible fruits. *Clusia flava* is called the Wild Mango, or Monkey-apple, in Jamaica. The "bitter Cola" seeds, not to be confounded with the true Cola, are yielded by a Guttiferous tree, probably a species of *Garcinia*.

HYPERICACEÆ. The St. John's Wort Order.

Coh. Guttiferales, *Benth. et Hook.*

Diagnosis.—Herbs or shrubs with opposite, entire, dotted leaves, without stipules; regular hermaphrodite flowers, the petals mostly oblique or convoluted in the bud; the many or few stamens polyadelphous, sometimes with glands between them; capsule 1-celled, with 2–5 placentas and as many styles (*Parnassia*), or 3–5-celled by union of the dissepiments in the centre; dehiscence septicidal; seeds numerous, apersipermic.—Illustrative Genera: *Hypericum*, L.; *Parnassia*, L. (aberrant form); *Vismia*, Velloz.

Affinities, &c.—This Order is not distantly removed from the Clusiaceæ; but the habit, the hermaphrodite flowers, usually distinct styles, the want of articulation of the peduncles and petioles, the numerous seeds, and the 5-merous floral envelopes generally afford distinctive marks. From Ternstrœmiads they differ in their cymose inflorescence and opposite leaves. The dark-coloured glands on the borders of the petals are very characteristic here, as also the polyadelphous stamens, which are sometimes regarded as instances of *chorisis*, but which more probably are compound stamens. These stamens are sometimes superposed to the petals, but in *Vismia guianensis* there is also a series of antisepalous scales, which restore the symmetry. The genus *Parnassia* differs from the rest of the Order in its alternate leaves and the stigmas opposite the parietal placentas; but in some species of *Hypericum* the axile placentas become drawn apart during the ripening of the seed, and show their really marginal origin; and the glands on the petals of *Parnassia* are probably related to the bundles of stamens of *Hypericum*. Bennett considers them as a modified inner row of petals. *Parnassia* is regarded by some as referable to Droseraceæ; it forms a link connecting the present Order

with Cistaceæ and, being sometimes perigynous, also with Saxifragaceæ, with which latter group, indeed, it is associated by Hooker. A. W. Bennett places it near Sauvagesiaceæ, and describes the movement of the stamens observable in this plant as a provision for securing cross fertilization.

Distribution.—There are a considerable number of species, distributed through 8 or 10 genera. The plants are generally dispersed throughout the temperate and warmer regions of the globe.

Qualities and Uses.—When a yellow juice resembling that of Clusiaceæ exists, it is more or less purgative, as in some American *Hyperica*, and still more in the species of *Vismia*, which yield a gum-resin like gamboge; that of *V. guianensis* (Mexico and Surinam) is known as American Gummi Gutta. In the European species of *Hypericum* the essential oil of the glands predominates over the yellow juice, and they are sometimes used as tonics and astringents. *H. Androsæmum* and the many other native species have a strong and peculiar odour, especially when dried; *H. hircinum* is fœtid.

REAUMURIACEÆ consist of a few plants scarcely separable from Hypericaceæ. They have shaggy seeds with a small quantity of perisperm, and a pair of appendages at the base of the petals. Bentham and Hooker refer them to Tamaricaceæ, from which they differ in their solitary flowers and floury perisperm.

ELATINACEÆ (WATER PEPPERS) are little annual marsh-plants, with opposite dotless leaves and membranaceous stipules; flowers minute, axillary; sepals and petals 2–5; capsule 2–5-celled, with an equal number of styles with capitate stigmas; seeds numerous, aperispermic. This little Order consists of a few species scattered all over the world, generally acrid in character. Their relations are variously regarded by different authors: formerly they were placed near *Alsineæ* in Caryophyllaceæ, from which their many-celled ovary divides them; they appear at least equally related to Hypericaceæ, from which they differ in the presence of stipules and the isomerous flowers; they come near to Zygophyllaceæ, as shown by Lindley, the transition being effected through the genus *Anatropa.*

SAPINDACEÆ. SOAP-WORTS.

Coh. Sapindales, *Benth. et Hook.*

Diagnosis.—Trees, shrubs, or rarely herbs, with simple or compound alternate or opposite leaves; flowers mostly unsymmetrical and irregular, the 4–5 sepals and petals imbricated in æstivation; the latter often provided with a scale at the base; the 5–10 stamens inserted on a fleshy hypogynous or perigynous disk; ovary 2–3-celled and lobed, with 2 (rarely more) ovules in each cell; embryo mostly curved or convoluted, without perisperm.

ILLUSTRATIVE GENERA.

Suborder 1. SAPINDEÆ. *Leaves usually alternate; flowers usually irregular; ovules mostly solitary; embryo curved or sometimes straight.*
Cardiospermum, *L.*
Paullinia, *L.*
Sapindus, *L.*
Cupania, *L.*

Suborder 2.

a cell, one ascending, the other suspended; embryo curved, with large consolidated cotyledons.

Æsculus, *L.*
Pavia, *Boerh.*

Suborder 3. DODONEÆ. *Leaves alternate; flowers regular; ovules 2 or 3 in a cell; embryo spiral.*
Kœlreuteria, *Lam.*
Ophiocaryon, *Schomb.*

Suborder 4. MELIOSMEÆ. *Leaves alternate; flowers very irregular, stamens 5, only 2*

cell, both suspended; embryo folded up; fruit a drupe.

Affinities, &c.—Some authors separate the *Hippocastaneæ* and make them a distinct Order, on account of the opposite leaves and the two ovules; and the *Meliosmeæ* (which are referred to Sabiaceæ by Bentham and Hooker) on account of the irregular flowers and drupaceous fruits; but these distinctions are esteemed insufficient. These plants are nearly related to Aceraceæ, especially by the samaroid fruits common here: the main distinctions are variable; for the two carpels, the opposite leaves, and the absence of scales on the petals and of an aril may be noted in Sapindaceæ: from Malpighiaceæ, which have samaroid fruit, they are distinguished by their unsymmetrical flowers. The peculiar convolution of the embryo is a very marked character in many of the Sapindaceæ, and is very curious in *Ophiocaryon*, the Snake-nut. The wood of the stems of some genera, such as *Sapindus*, *Paullinia*, &c., presents anomalous conditions from the distribution of the fibro-vascular structures into several groups, so that the trunks have a number of woody axes besides that surrounding the pith, all enclosed in a common bark.

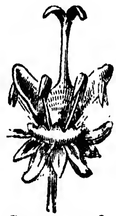
Distribution.—The members of this large group are natives of the tropics, especially of South America and India; some occur in North America and other temperate regions; the Horse-chestnut is only naturalized in Europe.

Qualities and Uses.—The properties of this Order are very various. They take their name from the saponaceous principle contained in the fruits of species of *Sapindus*, *S. Saponaria* &c., which makes a lather with water; hence the fruits are used for washing both in the East and West Indies; the Horse-chestnut, *Æsculus Hippocastanum*, possesses it to a certain extent. The fruits of *Sapindus* are acrid; and the juice of the leaves and bark of some species is poisonous, as are the seeds of *S. sene-* The fruit and leaves of the American Horse-chestnut or Buckeye, *Æsculus ohioensis*, are said to be actively poisonous, while the seeds of *Æ. Hippocastanum* are given to sheep in Switzerland. The Paullinias are very poisonous, from an acrid narcotic principle; yet *P. sorbilis* furnishes in its fruits an article of food for the Brazilian aborigines, called Guarana bread. Guaranine, an alkaloid extracted from various species of *Paullinia*, has properties like those of Theine. Other plants produce deli-

cious fruits, such as the Chinese Litchi, the Longan and the Rambutan, from species of *Nephelium*; and the fruits of *Schmidelia edulis* (Brazil), *Melicocca bijuga* (West Indies and Brazil), *Pappea capensis, Cupania sapida, Paullinia subrotunda, Schleichera trijuga, Sapindus esculentus*, &c. are all eaten.

STAPHYLEACEÆ, comprising a small number of species, were formerly regarded as related to Celastraceæ, but are now placed near Sapindaceæ, from which they differ chiefly in their stipulate, opposite, pinnate leaves, symmetrical flowers, perispermic seeds, and straight embryo. They are of little importance; the species of *Staphylea* are scattered all over the world. *S. pinnata*, the Bladder-nut, a native shrub, has oily and slightly purgative seeds.

Fig. 359.



Stamens and ovary of *Acer*.

Fig. 360.

Embryo of *Acer* extracted from the seed.

ACERACEÆ (MAPLES), a suborder of Sapindaceæ, *Benth. et Hook.*, comprise trees or shrubs with opposite leaves; regular, unsymmetrical, polygamous or diœcious, sometimes apetalous flowers; stamens on a fleshy disk (fig. 359); ovary 2-lobed, 2-celled, with 2 ovules in each cell; fruit a double samara, with 1 seed in each cell; seeds without perisperm; cotyledons folded, radicle inferior. —Illustrative Genera: *Acer*, L., *Negundo*, Mœnch.

Affinities, &c.—Nearly related to Sapindaceæ, and placed with them by Bentham and Hooker, from which, however, they differ in their opposite leaves and petals without scales; allied also to Malpighiaceæ, from which they differ in the absence of glands on the calyx, superior radicle, and other characters.

Distribution.—The group consists of 60 to 70 species, natives of the temperate parts of Europe, Asia, and North America. Traces of them are first observable in the Lower Miocene formation.

Qualities and Uses.—Chiefly remarkable for the sap, from which abundance of sugar is obtained in spring, especially from *A. saccharinum* (North America). Their light and handsome timber is also valued for joinery &c. The bark is astringent, and used in dyeing. *A. campestre*, native Maple, and *A. pseudo-platanus*, the Sycamore, are common trees in Britain. *A. Negundo* and various other kinds of Maple have been introduced from North America on account of their beauty as ornamental trees, especially in autumn.

POLYGALACEÆ. MILK-WORTS.

Coh. Polygalineæ, *Benth. et Hook.*

Diagnosis.—Herbs or shrubs with alternate, exstipulate, simple leaves; irregular hermaphrodite flowers; 4–8 diadelphous or

monadelphous stamens; the anthers 1–2-celled, opening at the apex by a pore or chink; fruit a 2-celled, 2-seeded pod; seeds carunculated.

Character.

Thalamus flat or oblique. *Calyx*: *sepals* 5, very irregular, distinct, often membranaceous; 3 placed exterior, 1 behind and 2 in front, the interior 2 (*wings*) lateral, usually petaloid. *Corolla*: *petals* usually 3, 1 anterior and large (*keel*) and 2 posterior, between the wings and posterior sepal of the calyx, and often coherent with the keel; sometimes 5, the additional 2 small, and placed between the wings and the anterior sepals on each side: the *keel* entire and with a fringe or crest, or 3-lobed and without a crest. *Stamens* hypogynous, 8, coherent in a tube, unequal and ascending: the tube split opposite the back sepal: or 4, distinct; *anthers* clavate, 1-celled, and opening by a terminal pore, or 2-celled. *Ovary* compound, 2–3-celled, one cell always suppressed in some cases; *ovules* suspended, solitary or twin: *style* and *stigma* simple, sometimes hooded. *Fruit* various, dry or succulent, sometimes winged; *seeds* pendulous, naked or with a hairy coat, a caruncle next the hilum; *embryo* straight or nearly so, in abundant perisperm.—Illustrative Genera: *Salomonia*, Lour.; *Polygala*, L.; *Mundtia*, Kunth; *Monnina*, Ruiz & Pav.; *Securidaca*, L.; *Xanthophyllum*, Roxb.; *Krameria*, Lœfll. (?).

Affinities, &c.—The relations of the Polygalaceæ have been a subject of much discussion among botanists. The irregular calyx and corolla, somewhat papilionaceous in *Polygala*, has led to a comparison to Leguminosæ, from which, however, they differ widely; moreover the odd petal is anterior in Polygalads, not next the axis as in Leguminosæ. The irregular petals, together with the hooded stigma, have suggested a relationship to Violaceæ; Brown pointed out their relation to Tremandraceæ, of which they may be considered irregular forms; *Krameria* has been referred by some writers to the Cæsalpineous division of the Leguminosæ. Most authors, however, are agreed that the nearest affinity is to Sapindaceæ. *Krameria* is raised to the rank of a distinct Order by a few writers, on account of the different corolla, composed of 5 petals, 4 (often free) stamens, and 1-celled ovary. *Moutabea* has sepals, petals, and stamens connate into a tube. *Xanthophyllum* has free stamens, 2-celled anthers, and a 1-celled fruit. Perisperm is sometimes wanting. The pollen in *Polygala* is elliptical, with numerous bands.

Distribution.—A large Order, nearly half the species of which are comprised in the genus *Polygala* and are very generally distributed; the others are mostly confined to particular quarters of the globe.

Qualities and Uses.—The plants of this Order are mostly bitter, and acid or astringent, with a milky juice in the root. The common Milkwort, *P. vulgaris*, and especially the form called *P. amara*, possesses bitter properties, but in less degree than *P. rubella* of North America.

Soulamea amara (Molucca) is said to be intensely bitter. The more active species of *Polygala* have emetic, purgative, and diuretic properties: *P. Senega*, the American Snake-root, with *P. sanguinea* and *purpurea*, the Cape *P. Serpentaria*, the European *P. chamæbuxus*, and the *P. crotalarioides* of the Himalayas &c., all show this property; and they are likewise all reputed antidotes against the poison of snakes. *P. venenosa* (Java) is regarded as a poison, the properties being excessively concentrated. *P. tinctoria* (North America) is used in dyeing. The bark of the root of a species of *Mundtia* contains a saponaceous substance, and is used for washing. *Krameria triandra* and other species, called Rhatany, are remarkable for the powerful astringent quality of the roots, which gives a deep red colour to an infusion. Rhatany-root is used in medicine, and is employed also to adulterate Port wine.

TREMANDRACEÆ are a small Order of plants related to Polygalaceæ, but with a regular, symmetrical flower, valvate calyx, free stamens, and seeds hooked at the chalazal end. They may be regarded as regular-flowered Polygalas. De Candolle placed them between Polygalaceæ and Pittosporaceæ.—They are slight, heathy shrubs, growing in Australia: 16 species are known, belonging to the genera *Tremandra*, *Tetratheca*, and *Platytheca*. They derive their name from the porous dehiscence of the anthers, and are of no known use.

MALPIGHIACEÆ.

Series Disciforæ; *Cohort* Geraniales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs, often climbers, with usually opposite or whorled, rarely alternate leaves; stipules generally short and deciduous, occasionally large and opposite the leaves; flowers perfect, or polygamous; calyx and corolla 5-merous, calyx with glands at the base of 1 or of all the segments; petals clawed; stamens mostly 10, often monadelphous with a thickened produced connective; carpels 3, or very rarely 2 or 4, wholly or partly coherent, often keeled; ovules solitary in the cells, pendulous from long funiculi; seeds aperispermic; embryo with mostly convolute thick or leafy cotyledons.—Illustrative Genera: *Malpighia*, Plum.; *Hiræa*; *Gaudichaudia*; *Banisteria*, L.

Affinities, &c.—The closest relations of this Order are Sapindaceæ and Aceraceæ, from which they are distinguished by their symmetrical flowers, and generally by the glands in the calyx, the long stalks to the petals, the small disk, and solitary ovule. Many of the species have dimorphic flowers. Some of the climbing kinds have stems of anomalous structure with several woody axes, without annual rings, enclosed in a common bark, or ultimately more or less separated from one another. *Nitraria*, a genus of saline plants, is sometimes separated as a distinct Order. Two or more embryos in the same seed occur in some species. The Order is a large one, comprising many genera and species, which latter are mostly Tropical-American. Their properties are generally unimportant; many of them have been introduced into our stoves on account of their showy flowers. The fruits of *Malpighia glabra* and *punicifolia* are eaten in the West Indies, under the name of Barbadoes Cherries. Munby supposes the

sedative or semi-intoxicating drupe of *Nitraria tridentata* (North Africa) to have been the Lotus of the ancients. The bark of most kinds is astringent; the hairs of some Malpighias sting powerfully.

ERYTHROXYLACEÆ are by some authors separated from the Malpighiaceæ on account of the calyx having no glands, while the petals present two membranous plates, on account of their capitate stigmas, and the absence of a long funiculus to the anatropous ovule. They are closely allied to *Linaceæ*, with which, indeed, they are associated by Bentham and Hooker, but differ in the presence of scales to the petals, their drupaceous fruit, and woody stem. They are shrubs, mostly belonging to one genus, *Erythroxylon*, and found most abundantly in Brazil; but a few are scattered all over the globe. They receive their name from the red colour of the wood of some kinds, such as *Erythroxylon hypericifolium* (Mauritius). The most remarkable plant of the Order is *E. Coca*, the leaves of which, under the name of Coca or Ipadu, are largely consumed in Peru and in Equatorial America, to produce a kind of intoxication; "Coca" is said to enable the natives to go two or three days without food; it is mixed with powdered chalk and chewed. Its properties are due to a principle like Theine, which arrests the sense of fatigue and hunger. Several species of *Erythroxylon* are recorded, and two or three belonging to other Genera.

MELIACEÆ.

Series Disciflorae; *Coh.* Geraniales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with alternate or somewhat opposite, simple or pinnate leaves, without stipules: flowers sometimes diclinous by abortion; calyx and corolla 3-, 4-, or 5-merous; stamens twice as many, coherent in a long tube or free; anthers sessile in the orifice of the tube; hypogynous disk sometimes cup-like; ovary free, compound, few- or many-celled; style 1; ovules 1–2, rarely 4 in a cell; fruit succulent or capsular, often 1-celled by abortion; seeds not winged; perisperm fleshy or absent.—Illustrative Genera: *Melia*, L.: *Trichilia*, L.; *Swietenia*, L.; *Cedrela*, L.

Affinities, &c.—Nearly related to Rutaceæ. It differs in the leaves, which are generally not dotted, and in the staminal tube; from Sapindaceæ in the ascending ovules, with ventral raphe. The species are numerous, and are found in the hotter parts of the globe generally; they possess bitter and astringent properties; some are powerfully purgative and emetic, such as *Guarea Aubletii* and *trichilioides*, *Trichilia emetica*, &c. *Melia Azedarach*, the Neem-tree, or Margosa, of the East Indies, is supposed to have febrifugal properties; its succulent pericarp yields an oil; and a kind of toddy is obtained by tapping it. *Carapa guineensis* yields a purgative oil, which is used also for lamps. *Lansium*, a genus of the East-Indian archipelago, yields an edible fruit called Langsat or Lanseh and Ayer-Ayer.

The Cedreleæ are distinguished from other Meliaceæ chiefly by the free stamens and the numerous winged seeds. *Chloroxylon* and *Flindersia* have dotted leaves. The plants are most common in the tropics of America and India. They have fragrant, aromatic, and tonic properties, and their timber is valuable. *Swietenia Mahogani* is the Mahogany-

tree; its bark, and that of *Cedrela Toona, febrifuga*, and other species, are used as substitutes for Cinchona. *Chloroxylon Swietenia* furnishes East-Indian Satin-wood; and an oil called Wood-oil is obtained from it. *Oxleya xanthoxyla* is the Yellow-wood of Australia.

AURANTIACEÆ. The Orange Order.

Series Discifloræ; *Tribe* of Rutaceæ, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with smooth, glandular alternate leaves, the blade jointed to the petiole; flowers regular, hermaphrodite, 3–5-merous; petals and stamens inserted on an hypogynous disk; stamens with flat filaments, distinct or coherent into one or several parcels; ovary many-celled, style single, terminal; fruit pulpy, often with a glandular leathery rind; seeds without perisperm; embryo with thick fleshy cotyledons and a short radicle next the hilum.—Illustrative Genera: *Triphasia*, Lour.; *Bergera*, Kœn.; *Cookia*, Sonner.; *Feronia*, Corr.; *Ægle*, Corr.; *Citrus*, L.

Affinities, &c.—The plants of this Order are by Bentham and Hooker classed as a tribe of *Rutaceæ*, and are nearly related to the Meliaceæ in the structure of the flowers, and still more closely to Amyridaceæ. In general they are distinguishable by the dotted leaves, with the blade (simple or compound) articulated to the petiole, the deciduous imbricated petals, and the succulent fruit. The relation to Rutaceæ is rendered clearer by occasional monstrosities of the fruit, from which some of the carpels grow out like horns. Sometimes a second circle of carpels is produced, forming, as it were, a double concentric fruit, comparable in some measure to the conditions in the Pomegranate, where, however, the whole fruit is enclosed in the excavated receptacle. The pulp of the Orange consists of cellular hairs produced from the wall of the fruit. The seeds of Oranges often contain two embryos; and they are remarkable for the development of ramified collections of spiral vessels at the chalazal end, within the testa, also for a peculiar coloration of the inner coat of the seed in this situation.

Distribution.—Chiefly East-Indian plants, but diffused by cultivation throughout the tropics, and even in the warmer temperate regions.

Qualities and Uses.—The most remarkable parts of these plants are their fruits; those of the genus *Citrus* being among the most valuable and best-known of imported fruits. The species of *Citrus* are not clearly defined, much difference of opinion existing as to the specific distinctness of certain forms, which, as in most cultivated plants, are much confused. *C. Aurantium* is the common Sweet Orange; *C. Bigaradia* or *C. vulgaris*, the bitter or Seville Orange, seems to be known only in cultivation, and is supposed by some to be a variety of the preceding. *C. Bergamia* is the Mellarosa or Bergamot Orange, which is also regarded as a variety of *C. Limetta*, the cultivated Sweet Lime; *C. acida* is the East-Indian Lime; *C. Limonum* is the ordinary Lemon; *C. Lumia* is the Sweet Lemon, cultivated in the South of Europe; *C. medica* is the Citron; *C. decumana* is the Shaddock; *C. Paradisi* the Forbidden-fruit; *C. Pompelmos* the Pompelmoose; and *C. japonica* the Kumquat. All these fruits have an abundant pulp, which varies chiefly in the degree of acidity and the

peculiar aroma; that of *C. Bigaradia* is also bitter. The rind of all is fragrant, from the presence of imbedded glands containing essential oil of aromatic and bitter character; the flowers partake of the aromatic quality. The oil of Neroli is obtained from the flower of *C. Bigaradia*; but the oil of the rind is also used for making Orange-flower water. Oil of Bergamot is from the flower and rind of the fruit of *C. Bergamia*; *huile de Cédrat* from *C. medica*; the essential oil of the Lemon-rind is also largely used. The rinds are also valued for their bitter and aromatic properties when dried or preserved with sugar. The dry rinds of Orange, Lemon, &c. are used as stomachics in medicine, in infusions and tinctures; and are also employed in the preparation of liqueurs and cordials, such as Curaçoa &c.; the fruit, rind, and pulp, when preserved with sugar, form "marmalade," the best being made from the Seville Orange. The acidity of the Lime and Lemon depends chiefly on the presence of citric acid, and renders them very valuable as antiscorbutic agents. *Ægle Marmelos*, the Bael-fruit, sometimes used in cases of dysentery, has a delicious fruit, which, however, is laxative; the rind is used as a vermifuge. *Cookia punctata* yields the Wampee, highly valued in China and the East-Indian Archipelago; and the fruits of other plants of the Order are eaten. The wood of all the trees is hard and compact; the foliage shares the fragrant character of the fruits, containing abundance of glands filled with aromatic, bitter essential oils. The Orange, Lemon, and their varieties are largely cultivated in the South of Europe in the open air; and in our conservatories they are everywhere prized, on account of their striking appearance when in fruit and the delicious perfume of the flowers. Orange- and Lemon-trees are wonderfully prolific of fruit; and the plants retain their vitality with great obstinacy when taken from the ground and transported to a distance, and when they are multiplied by cuttings.

LINACEÆ. THE FLAX ORDER.

Series Disciflorae; *Coh.* Geraniales, *Benth. et Hook.*

Diagnosis.—Herbs, or sometimes shrubs, without stipules; with regular symmetrical hermaphrodite flowers, 4–5-merous throughout; calyx imbricated; petals convolute in æstivation; stamens usually 5, coherent at the base, often with intervening sterile stamens; ovary compound, of about as many carpels as there are sepals; styles distinct; capsule many-celled, each cell divided more or less perfectly into two by a false septum from the dorsal suture, each compartment with one seed, having a straight oily embryo and with, or rarely without, perisperm.—Illustrative Genera: *Linum*, L.; *Radiola*, Dillen.

Affinities, &c.—Most nearly related to Oxalidaceæ, but likewise connected with Caryophyllaceæ, Malvaceæ, and Geraniaceæ by the general structure of the flowers, the coherent stamens, &c.; but the simple entire leaves and the peculiar structure of the capsules are very distinctive marks. From Malpighiaceæ they differ in their glandless calyx.

Distribution.—A small Order, generally diffused, but most abundantly so in Europe and North Africa.

Qualities and Uses.—*Linum catharticum*, a native weed, has active purgative properties; but the most important plant of the Order is *L. usitatissimum*, the liber-fibres of which constitute Flax, while the seeds,

known as Linseed, yield a most valuable drying-oil, and their cake forms an excellent material for fattening cattle. The flowers of many species of *Linum* are very showy (blue, yellow, pink, &c.), but are mostly fugacious. The flowers of some are dimorphic.

OXALIDACEÆ. Wood-Sorrels.

Series Discifloræ; *Tribe* of Geraniaceæ, *Benth. et Hook.*

Diagnosis.—Herbs, or rarely shrubs or trees, with an acid juice; mostly compound alternate leaves; regular, symmetrical, hermaphrodite, 5-merous flowers; calyx imbricated, and petals convolute in æstivation; stamens 10, somewhat monadelphous; styles 5, separate; capsule 5-celled, several-seeded; seeds perispermic; embryo straight or curved. Radicle superior.—Illustrative Genera: *Oxalis*, L.; *Averrhoa*, L.

Affinities, &c.—Nearly related to Geraniaceæ, with which Bentham and Hooker unite them. From Linaceæ they may generally be distinguished by their compound leaves; but the septa in the capsules of that Order afford the most constant distinction. The seeds of *Oxalis* have an elastic fleshy coat, which opens with elasticity and expels the seed when ripe. Some regard this as an aril, others as a development of the testa. The leaves of many kinds are sensitive, especially *Oxalis sensitiva* and *Averrhoa Bilimbi*; but others possess the quality in lower degree. *O. bupleurifolia* and some other species have phyllodes.

Distribution.—A rather large Order, the members of which are generally diffused in temperate and hot climates; most abundant in America and at the Cape of Good Hope. The shrubby kinds belong to hot climates.

Qualities and Uses.—The most marked property of *Oxalis* is the acid juice, depending on the presence of oxalic acid. *O. Acetosella*, Wood-sorrel, abounds in our woods. *Averrhoa Bilimbi*, the Blimbing, *A. Carambola*, the Carambole of the East Indies, have acid fruits, which are eaten by the natives, but used chiefly as pickles by Europeans. Some species of *Oxalis* have tubers furnishing wholesome food. *O. crenata* (Arracacha) is used like potatoes in Columbia; *O. Deppei* has roots as large as small parsneps. The tubers of *O. anthelmintica*, the Mitcha-mitcho of Abyssinia, are said to be valuable as an anthelmintic. Many kinds are cultivated on account of the beauty of their flowers.

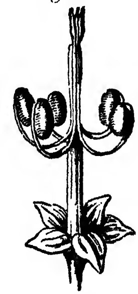
GERANIACEÆ. Crane's-bills.

Series Disciforæ; *Coh.* Geraniales, *Benth. et. Hook.*

Diagnosis.—Herbs or shrubs, with articulated swollen stem-joints; opposite or alternate leaves, and membranous stipules; regular or irregular, symmetrical, hermaphrodite, 5-merous flowers; sepals imbricated and petals contorted in æstivation; stamens mostly 10, coherent at the base, the alternate ones shorter and sometimes barren; carpels 5, adherent to a central prolonged axis (carpophore), from which they separate when ripe by the elastic curling-back of the segments of the style, carrying away the 1-seeded dehiscent cocci (fig. 361).—Illustrative Genera: *Erodium*, Hérit.; *Geranium*, Hérit.; *Monsonia*, L.; *Pelargonium*, Hérit.

Affinities, &c.—Many points of affinity exist with Oxalidaceæ, Linaceæ, and Balsaminaceæ, likewise with Tropæolaceæ, and, less important ones, with Zygophyllaceæ. The arrangement of the carpels round a column, the palmate leaves of some kinds, the monadelphous stamens, and the convoluted embryo cause a good deal of resemblance to some of the Malvaceæ. The peculiar fruit, the stipules, the swollen joints of the stem, and the convoluted embryo separate this Order from the nearest allies. From Malvaceæ it may be distinguished at once by the imbricated æstivation of the calyx. *Pelargonium* is remarkable for a spur or pouch extending from the base of the calyx and adherent to the peduncle. Most of the plants have aromatic oil contained in glandular hairs, giving a musky or other strong odour.

Fig. 361.



Fruit of *Geranium*, with the carpophore and carpels.

Distribution.—The species are numerous. *Geranium* and *Erodium* belong chiefly to the temperate parts of the Northern Hemisphere. *Pelargonium* abounds at the Cape of Good Hope, and occurs in Australia. One species is found in Asia Minor.

Qualities and Uses.—Astringent and aromatic properties are general. The common weed *G. Robertianum* had a reputation formerly, and the *G. maculatum*, or Alum-root of North America, is a powerful astringent, containing a large amount of tannin. The species of *Erodium* which emit a musky odour are said to have similar properties. Some have tuberous roots; that of *Pelargonium triste* is eaten at the Cape of Good Hope. The species of *Pelargonium* are remarkable for the beauty of their flowers, which are more or less irregular and spurred, and have great susceptibility of improvement by culture, and a tendency to run into varieties, rendering them established "florist's flowers." Many of them have zones or belts of colour in the leaves. The species of *Geranium* proper have regular flowers without spurs; others are very fragrant.

BALSAMINACEÆ. Balsams.

Series Disciflora; *Tribe* of Geraniaceæ, *Benth. et Hook.*

Diagnosis.—Annual plants with succulent stems, full of bland watery sap; flowers hermaphrodite, very irregular; stamens 5, somewhat united; the fruit mostly bursting elastically when ripe. Embryo straight, aperispermic. Radicle superior.—Illustrative Genera: *Impatiens*, L.; *Hydrocera*, Blum.

Affinities, &c.—This Order is nearly related to Geraniaceæ, and is included in that family by Bentham and Hooker, but may be distinguished by the want of the peculiar carpophore of that Family, and by the much greater irregularity of the flower; the irregular flower also separates it from Oxalidaceæ and other allied Orders. This irregular flower does not really depart widely from a symmetrical condition: it is completely 5-merous, except in the suppression in *Impatiens* of the petal opposite the bract

(which is developed in *Hydrocera*); the two small lateral sepals, the spur, and the double segment on the opposite side to the spur form an imbricated calyx of five parts; the odd petal opposite the two confluent sepals is suppressed, and the others are generally combined into two 2-lobed bodies, but are sometimes free; in single flowers the stamens alternate with these; in double cultivated flowers a second corolline circle of five petals sometimes appears in the place of the stamens, and the stamens alternate again with these. The structure of the ovary and its mode of dehiscence are also deserving of notice. The name of the genus *Impatiens* is derived from the elasticity with which the capsule bursts when touched after the seeds are ripe. The species are rather numerous. A few are scattered over the globe; but the majority are East-Indian. Their properties are unimportant. *I. Balsamina* is a valued tender annual plant; *I. Noli-me-tangere* grows in the north of England; and *I. fulva* (North America) is naturalized in some places in Southern England.

VIVIANACEÆ are a small Order of South-American herbs or half-shrubby plants, related to Geraniaceæ, but having a valvate calyx and perispermic seeds. Properties unknown.

TROPÆOLACEÆ. GARDEN-NASTURTIUMS.

Series Discifloræ; *Tribe* Pelargonieæ *of* Geraniaceæ, *Benth. et Hook.*

Diagnosis.—Smooth trailing or climbing herbs with a pungent juice; leaves alternate, exstipulate; flowers axillary, irregular, perfect; sepals 3–5, the upper or posterior one spurred; petals 1–5; stamens 6–10, perigynous, distinct; ovary superior, of 3 or 5 carpels; style single; stigmas 3–5; ovules pendulous, 1 in each carpel; fruit dry; carpels separating as indehiscent achenes from a central axis; seeds large, aperispermic.—Illustrative Genera: *Tropæolum*, L.; *Chymocarpus*, Don.

Affinities, &c.—A small Order of plants, natives of the temperate parts of South America, related to Limnanthaceæ, Malvaceæ, and Geraniaceæ, and included in the latter family by Bentham and Hooker. The genus *Tropæolum* contains the garden Nasturtiums, or Indian Cresses, notable for their pungent juice, somewhat like that of Cruciferæ. Various species have a tuberous root; that of *T. tuberosum* is eaten in Peru. The spur of the calyx of *Tropæolum* is curious, resembling that of *Pelargonium*, but is free from the peduncle. In some cases it would seem to be a tubular process from the receptacle. The flowers are mostly showy and of great variety of colour. The Canary Creeper, *T. peregrinum* or *aduncum*, may be noticed for the power of the full-grown plant to obtain its nourishment apparently almost entirely from the atmosphere, and for its climbing by twining its petioles, like *Clematis*.

LIMNANTHACEÆ, a small Order of North-American plants, are chiefly distinguished from Tropæolaceæ, with which they are associated in the family *Geraniaceæ* by Bentham and Hooker, by their regular flowers, erect ovules, and the adherence of the stamens to the calyx. Their properties are analogous. *Limnanthes* (California) has showy flowers. *Floerkea* (United States) is a mere weed.

ZYGOPHYLLACEÆ. Bean-Capers.

Series Disciflorae; *Coh.* Geraniales, *Hook. et Benth.*

Diagnosis.—Herbs, shrubs, or trees with opposite stipulate, mostly imparipinnate, not dotted leaves; calyx and corolla 4–5-merous, imbricated in æstivation; stamens twice as many, hypogynous, each often at the back of a scale; ovary surrounded by glands or a toothed disk, more or less deeply 4–5-lobed, 4–5-celled; fruit capsular; dehiscence valvular or into cocci; few-seeded; perisperm sparing or none.—Illustrative Genera: *Tribulus*, Tournef.; *Peganum*, L.; *Fagonia*, Tournef.; *Zygophyllum*, L.; *Larrea*, Cav.; *Guaiacum*, Plum.; *Melianthus*, L. (?).

Affinities, &c.—This order is very closely allied to Rutaceæ (but differs in habit, the scaly stamens, and dotless leaves) through *Peganum*, which is placed here chiefly on account of its stipulate, not dotted, opposite leaves. With Simarubaceæ it agrees in the attachment of the stamens at the back of a scale, but differs in the short styles. *Melianthus* is an anomalous genus, which by some authors is taken as the type of a distinct Order supposed to have its nearest relations in Geraniaceæ and Sapindaceæ. Zygophylleæ are closely related to Malpighiaceæ, but differ in their glandless calyces, scaly stamens, &c.

Distribution.—The species are not very numerous, and are chiefly found in the warm temperate regions of the globe. *Zygophyllum* and *Tribulus* are especially characteristic of dry regions of Egypt, Arabia, and Scinde.

Qualities and Uses.—The so-called gum-resin, Guaiacum, is derived from *Guaiacum officinale*, the bark and wood of which are also employed as diaphoretic and sudorific agents; *G. sanctum* has similar properties. The leaves of these and of *Porliera* are used in place of soap for scouring in the West Indies. The remarkably hard wood called Lignum Vitæ is derived from *Guaiacum officinale* or some other species; all the arborescent plants of this Order have extremely hard wood. The flowers of *Zygophyllum Fabago* are used in the East for pickles, under the name of Bean-capers. The seeds of *Peganum Harmala* are used as spice in Turkey, and also in the production of the celebrated Turkey-red dye for cotton. *Larrea mexicana* is known by the name of the Creasote-plant. *Zygophyllum simplex* has a very bad odour.

RUTACEÆ. The Rue Order.

Series Disciflorae; *Coh.* Geraniales, *Benth. et Hook.*

Diagnosis.—Herbs, shrubs, or trees with simple or compound exstipulate leaves, dotted with transparent glands containing aromatic or acrid oil; flowers regular, 3–5-merous; the stamens equal to or twice as many as the sepals; the 2–5 pistils separate or combined into a compound ovary with as many cells, sessile or raised on a prolongation of the receptacle (gynophore) or glandular disk; style simple, or divided below; fruit with the carpels either coherent or separating and bursting by one or both sutures; seeds in pairs or solitary; perisperm present or absent, radicle superior.—Illustrative Genera: *Galipea*, Aubl.; *Ticorea*, Aubl.;

Boronia, Smith; *Eriostemon*, Smith; *Correa*, Smith; *Diosma*, L.; *Barosma*, Willd.; *Dictamnus*, L.; *Ruta*, Tournef.

Affinities, &c.—This large Order is sometimes divided into two, Rutaceæ and Diosmeæ, the latter including the greater part of the genera; but the distinctions seem insufficient—the *Boronieæ*, which have the separable endocarp supposed to be characteristic of *Diosmeæ*, having perispermic seeds like *Ruteæ*. Bentham and Hooker make the order a very comprehensive one by including the following as tribes:—1. Cusparieæ, 2. Ruteæ, 3. Diosmeæ, 4. Boronieæ, 5. Xanthoxyleæ, 6. Toddalieæ, 7. Aurantieæ (see *ante*, p. 235). Most of these are separately treated in the present work, as being more readily understood by beginners. The Order is connected with Zygophyllaceæ by *Peganum*; it is related also to Xanthoxylaceæ, which are perhaps merely polygamous Rutaceæ. There is also an affinity with Aurantiaceæ (which differ, however, in the fruit), and with Anacardiaceæ. *Correa*, with its monopetalous corolla, seems to approach Ericaceæ, to which the *Boronieæ* have much resemblance in habit. From Simarubaceæ and Terebinthaceæ Rutals differ in their glandular leaves and in the nature of the fruit.

Distribution.—*Ruta* and its allies are found chiefly in Europe and North Asia; *Diosma*, *Barosma*, &c. at the Cape of Good Hope; *Boronia*, *Eriostemon*, &c. in Australia; and *Galipea*, *Esenbeckia*, and their related genera in Equinoctial America.

Qualities and Uses.—Generally remarkable for a strong aromatic or fœtid odour, and possessing antispasmodic and tonic properties. Angostura bark is derived from *Galipea officinalis*, and apparently from *G. Cusparia* (*Bonplandia trifoliata*); Melambo bark probably from some allied plant. The bark of *Esenbeckia febrifuga* is used in place of Cinchona in Brazil; and that of *Ticorea febrifuga* is another of the "Quinas" of Brazil. The Bucku plants of South Africa are species of *Barosma*, *Diosma*, and their allies; their foliage, which is extremely glandular, has a very strong odour; and *D. crenata*, *serratifolia*, and others are used as antispasmodic and diuretic agents. The leaves and unripe fruits of Rue (*Ruta graveolens*) are antispasmodic, and are also said to be emmenagogue and anthelmintic: *R. montana* is acrid; and its juice is described as vesicating the skin, and even producing erysipelas and ulceration. The leaves of *Correa alba* and other species are used by the settlers in Australia for Tea. Many of the Rutaceæ are favourite greenhouse plants, such as *Boronia*, *Eriostemon*, &c. *Dictamnus Fraxinella*, a South-European plant, common in our gardens, is very glandular, and it is said that the volatile oil renders the atmosphere about the plant inflammable in very hot weather. This account requires confirmation. These glandular plants are of course very inflammable in themselves. The root of *Toddalia aculeata* is used in India as an aromatic.

XANTHOXYLACEÆ are trees or shrubs with alternate or opposite, exstipulate, simple or compound, dotted leaves, and flowers resembling those of Rutaceæ in almost every respect, except that they are constantly polygamous, and sometimes have succulent fruit; seeds perispermic.—Illustrative Genera: *Xanthoxylon*, Kunth; *Ptelea*, L.

Affinities, &c.—The Xanthoxylaceæ are united by some authors with the Rutaceæ; their more remote relations are with Aurantiaceæ and Ana-

cardiaceæ, which, however, not only differ in their fruits, but their seeds have no perisperm. There is a considerable affinity to the Euphorbiaceæ and to *Fraxinus* among the Oleaceæ, *Ptelea* having even a samaroid fruit.

Distribution.—The species are not very numerous, and are generally distributed, but are most abundant in America.

Qualities and Uses.—Pungent and aromatic. *Xanthoxylon*, a genus represented in North and South America, as well as in India, China, &c., eminently possesses these characters, its species being commonly called Peppers in their native countries. *X. Clava* and *fraxineum* (North America) are powerful diaphoretics and sudorifics; *X. nitidum* (China) has a similar reputation; *X. hyemale* (Brazil), *X. piperitum* (China), &c. are analogous. The unripe capsules of *X. Rhetsa* are aromatic, resembling orange-peel. The fruit of *Ptelea* has a strong aromatic bitter taste, and has been used as a substitute for hops.

SIMARUBACEÆ are trees or shrubs with alternate exstipulate leaves, without dots, usually compound; flowers diclinous or polygamous; calyx and corolla 4-5-merous; stamens 8–10, emerging from an hypogynous disk, filaments usually with a scale at the back; anthers bursting longitudinally; ovary stipitate, 4–5-lobed; fruit of 4–5 indehiscent drupes round a common receptacle, or capsular or samaroid, with 1 pendulous aperispermic seed in each compartment.—Illustrative Genera: *Quassia*, L.; *Simaruba*, Aubl.; *Ailanthus*, Desf.

Affinities, &c.—Belonging to the Rutaceous group, these plants are most closely allied to the Zygophyllaceæ by the stamens and dotless leaves, to the Ochnaceæ by the deeply lobed ovary,—differing from the former in the structure of the fruit and the number of seeds in a cell, from the latter by the absence of a large disk and the dehiscence of the stamens.

Distribution.—A small Order, the members of which inhabit South America, Africa, the East Indies, and the Malay archipelago. *Cneorum* occurs in the Mediterranean district.

Qualities and Uses.—The most striking property is great bitterness, whence they are used as tonics. Quassia or Bitterwood, used as a tonic, as a fly-poison, and as a substitute for hops in beer, is derived from this family. *Quassia amara* (Surinam) is stated to be the true plant; but *Picrasma* or *Picræna excelsa* yields the wood usually imported. The bark of the root of *Simaruba amara* is used in the same manner. *Brucea antidysenterica* has similar qualities, and was formerly mistakenly supposed to be the source of false Angostura bark. *Simaba Cedron* has a reputation for curing snake-bites; but recent experiments throw doubt on this. *Ailanthus glandulosa*, the "tree of heaven," is commonly grown for ornament in this country; its leaves afford nutriment to a species of silkworm.

OCHNACEÆ are scarcely separable from Simarubaceæ; but the ovary is composed of carpels seated on a large fleshy disk instead of upon a stipe, the elongated anthers often open by pores, and the simple leaves are without stipules. The thick gynophore of this Order affords a close connexion between Rutaceæ and Geraniaceæ. The properties are similar to those of Simarubaceæ.

CORIARIEÆ is the name applied to a small group of plants belonging to one genus, *Coriaria*, of obscure affinities, placed in this neighbourhood

by Lindley, but differing from most of the Rutales in their pendulous ovules with dorsal raphe. In some respects they approach *Phytolaccæ* and *Tropæoleæ.*—These plants have dangerous properties. Of *C. myrtifolia* the leaves, which are sometimes used to adulterate Senna, are said to produce tetanus; the berries are poisonous. The fruits of other species are said to be edible, but the seeds poisonous. *C. myrtifolia* and *ruscifolia* are used in dyeing, infusion of the leaves giving a dark blue with sulphate of iron.

PITTOSPORACEÆ are trees or shrubs, often climbing plants, with alternate exstipulate leaves; flowers regular; calyx and corolla 4–5-merous, imbricated, deciduous; stamens 5, hypogynous, alternate with the petals, opening longitudinally or by apical pores; ovary free, 2-celled and sometimes with 2–3 imperfect cells; style single, stigmas equal to the placentas; ovules horizontal or ascending, anatropous; seeds numerous; embryo minute, in fleshy perisperm.—Illustrative Genera: *Pittosporum*, Soland.; *Sollya*, Lindl.; *Billardiera*, Smith.

Affinities, &c.—A small Order, placed by DeCandolle between Polygalaceæ and Frankeniaceæ, by A. Richard near Rutaceæ, by Endlicher in the neighbourhood of Rhamnaceæ. Lindley regards them as near Vitaceæ. From Tremandraceæ and Olacaceæ they differ in their imbricate sepals and petals and their numerous ovules. In other points they resemble Celastrineæ, but they have no disk and no aril. Decaisne points out an affinity with some Ericads, as *Ledum*. The plants are chiefly from Australia; the berries of *Billardiera* are eaten, having a pleasant acid flavour; but a resinous quality pervades the whole Order. Some of the species are cultivated on account of their flowers and coloured berries, as *Sollya*, *Billardiera*, &c.

VITACEÆ. Vines.

Series Discifloræ; *Coh.* Celastrales, *Benth. et Hook.*

Diagnosis.—Shrubs with a watery juice, usually climbing by tendrils, placed opposite the leaves, with small regular flowers, a minute truncated calyx with the limb mostly obsolete; stamens as many as the valvate petals, and superposed to them, springing from a disk surrounding the ovary. Fruit succulent; seeds bony; perisperm hard.—Illustrative Genera: *Vitis*, L.; *Pterisanthes*, Blum.

Affinities, &c.—The relations of this Order, sometimes called Ampelideæ, are somewhat complex; a portion of the plants are related to Meliaceæ, Celastrineæ, and Rhamnaceæ; but the nearest connexion would appear to be to the epigynous Order Araliaceæ, especially through the Ivy, *Hedera*. The characters of the group, however, are very distinct, in the hypogynous stamens superposed to the petals, and the climbing habit. The superposition of the stamens to the petals is due to the abortion of five antisepalous stamens, which are sometimes represented by five glands of the disk. The tendrils by which the stems climb are flower-branches, often exhibiting a few nodules representing abortive flowers. They are extraaxillary, and are considered by some to be terminal buds deflexed, by others as formed by a partition of the growing point, one division

forming the tendril, the other the shoot. In *Ampelopsis* Dutailly thinks the tendril is an axillary bud which remains attached to the stem, elongates with it, and ultimately separates from it some distance above the axil in which it originates. In some cultivated Vines the seeds are constantly suppressed, while the fruit is perfected, as in the varieties yielding the Sultana raisins and the Zante grape or "Currant." *Pterisanthes*, a Javan plant, has a very extraordinary structure: its numerous barren and fertile flowers are developed on a very large foliaceous peduncle having the form of a number of divergent plates set edgewise at the end of a long slender stalk; the fertile flowers and berries are sessile on both surfaces of the laminæ, the edges being fringed with stalked barren flowers. The separation of the petals at their bases, remaining coherent above so as to form little 5-rayed stars, is worthy of notice in this Order. The species of *Ampelopsis*, known as "Virginia Creepers," exhibit some interesting phenomena, viz. the assumption of a crimson colour by the foliage in autumn, and the adaptation of their tendrils to form organs of attachment to walls: the points of the tendrils are negatively heliotrophic, and insinuate themselves into little holes and cracks, especially in brickwork, and then expand inside the cavities so as to fix themselves as the stone masons fix their "lewis," or key, into large blocks of stone.

Distribution.—The genus *Vitis*, including *Ampelopsis* and *Cissus*, contains a large number of species, natives for the most part of tropical and subtropical regions. The remaining genera have only a very few representatives. The Vine (*Vitis vinifera*) is supposed to be a native of the shores of the Caspian; but it has run wild in South Europe, and is cultivated all over the world where the temperature is not too low or too high: in the last case it runs away to leaf and does not produce fruit. The stems and roots of some of the *Cissi* in the East Indies are infested by the parasitical Rafflesiaceæ and Balanophoraceæ. In a fossil state they have been found in Miocene as well as in more recent deposits.

Qualities and Uses.—The properties of the Vine (*Vitis vinifera*), with its innumerable varieties, are universally known; the Fox-grapes (*Vitis vulpina* and *Labrusca*) of North America have similar properties when cultivated, but are inferior. The berries of the *Cissi* are acrid; some yield a colouring-matter. The sap of the stems and leaves generally of the Order is sour, containing tartaric acid.

Series 2. CALYCIFLORÆ.

Flowers usually with a calyx and corolla; the petals distinct, springing from the calyx or from a perigynous disk; the stamens perigynous or epigynous.

Exceptions, &c.—The character of this Subclass, founded on the insertion of the petals and stamens upon the calyx, is very artificial, and is liable to exception in certain genera of Orders referable here. On the other hand, it is met with exceptionally in Thalamifloral Orders; and many cases occur where the conditions are difficult to ascertain. Moreover it causes the separation of very natural groups of Orders, such as the removal of Anacardiaceæ, which has both hypogynous and perigynous genera, from the Sub-

class which includes the Rutaceæ, in accordance with the structure of the majority. Bentham and Hooker, apparently with a view to remove some of these anomalies, have proposed a subclass or series which they call Discifloræ, the most important character of which consists in the presence of a large disk or expansion of the receptacle attached to the calyx or to the ovary, and from which the petals and stamens spring; it thus includes some Thalamifloral and some Calycifloral Orders (including the Orders comprised in the cohorts Geraniales, Olacales, Celastrales, and Sapindales). The separation of the Perigynous from the Epigynous Orders is rendered impracticable by the occurrence of the two conditions in one Order, as in Rosaceæ. United petals occur in some exceptional cases, as in Cucurbitaceæ.

CELASTRACEÆ. The Spindle-tree Order.

Series Discifloræ; *Coh.* Celastrales, *Benth. et Hook.*

Diagnosis.—Shrubs with simple, mostly alternate leaves, and with small deciduous stipules; small regular flowers, the 4–5 sepals and petals imbricated in æstivation; stamens as many as the petals and alternate with them, inserted on a disk filling up the bottom of the calyx; seeds mostly arillate, perispermic.—Illustrative Genera: *Euonymus*, Tournef.; *Celastrus*, Kunth; *Catha*, Forsk.; *Elæodendron*, Jacq.

Affinities, &c.—Related to Rhamnaceæ, differing in the imbricated calyx and the stamens alternating with the petals. Aquifoliaceæ, a sympetalous Order, is very nearly allied; but the Celastraceæ appear to have closer relations with some Thalamifloral Orders, such as Malpighiaceæ through Hippocrateaceæ. The fleshy coat of the seed of *Euonymus* is described by Planchon as an *arillode* or false arillus, arising from the margin of the micropyle.

Distribution.—A large Order, the species of which are generally diffused, but more abundant outside the tropics.

Qualities and Uses.—More or less acrid, with oily seeds. *Euonymus europæus*, the common Spindle-tree of our hedges, is used for gunpowder-charcoal. The inner bark of *E. tingens* is used in dyeing; the seeds of *E. europæus* are said to be purgative and emetic. The bark of *Celastrus scandens* has the same properties. *Catha edulis* has stimulant properties, and the leaves are largely used by the Arabs under the name of *Kat*. The drupaceous fruits of *Elæodendron Kubu* are eaten at the Cape of Good Hope.

Stackhousiaceæ constitute a small Order of Australian plants intermediate between Celastraceæ and Euphorbiaceæ; their corolla is sympetalous.

Hippocrateaceæ, which have hypogynous petals and more or less epigynous stamens, are most nearly related to Celastraceæ (with which, indeed, they are combined by Bentham and Hooker), connecting them with Malpighiaceæ, Aceraceæ, and through *Staphylea* with Sapindaceæ, &c. They are chiefly South-American trees or climbing shrubs, some with edible fruit.

Chailletiaceæ is another small Order, usually placed in this neighbourhood, but with obscure affinities. *Chailletia toxicaria* has a poisonous fruit, called Rat's-bane at Sierra Leone.

RHAMNACEÆ. The Buckthorn Order.

Series Disciflore ; *Coh.* Celastrales, *Benth. et Hook.*

Diagnosis.—Shrubs or small trees with simple, alternate, stipulate, or exstipulate leaves; small and regular flowers (sometimes apetalous); the 4–5 perigynous stamens as many as the valvate sepals, and alternate with them (superposed to the petals when these are present); disk fleshy; ovary free or inferior; berry or pod with one seed in each cell, perispermic, without an aril.—Illustrative Genera: *Ventilago*; *Paliurus*, Tournef.; *Rhamnus*, Juss.; *Hovenia*, Thunb.; *Colletia*; *Gouania*.

Affinities, &c.—The Rhamnaceæ are clearly distinguished from the Celastraceæ by the position of the stamens before the petals. The calycifloral condition of their stamens, the fleshy disk, and the separate petals indicate great difference from the corollifloral Order Aquifoliaceæ, also formerly associated with them. Brongniart thinks their nearest relations are to the hypogynous Byttneriaceæ and to Euphorbiaceæ. Some of the genera have free, others adherent ovaries.

Distribution.—A rather large Order, the species of which are generally diffused.

Qualities and Uses.—Some acrid and purgative, some with bitter tonic properties, others with edible fruits. *Rhamnus* includes *R. catharticus*, the Buckthorn, from the berries of which a purgative syrup is made, also the colour termed Sap-green. The dyeing material called French berries consists of the unripe berries of *R. infectorius*, *saxatilis*, and *amygdalinus*. *Zizyphus* has edible fruit, called Jujubes (*Z. vulgaris*, *Z. Jujuba*, &c.). The charcoal made from the wood of *R. Frangula* is used for gunpowder-making under the name Dog-wood. *Z. Lotus* is supposed by some to be the Lotus of the ancients, although others think this was *Nitraria*. The peduncles of *Hovenia dulcis* enlarge into a succulent fruit, eaten in China; other genera also furnish edible berries. The leaves of *Ceanothus americanus* are consumed as New-Jersey Tea, and those of *Sageretia theezans* are used for Tea by the poorer Chinese.

ANACARDIACEÆ or TEREBINTHACEÆ.

The Sumach Order.

Series Disciflore ; *Coh.* Sapindales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with a resinous or milky acrid juice; dotless alternate leaves, and small, often polygamous, regular flowers; calyx small, usually with 5, sometimes 3–4 or 7 lobes, persistent; petals equal in number to the lobes of the calyx, or wanting; stamens the same number or double or more, inserted on an annular fleshy disk, or coherent and perigynous. Ovary single, or rarely of 5 or 6 carpels, superior (rarely

inferior), 1-celled; style 1, or 3 or 4, sometimes none; stigmas twice as many; ovules solitary, on a long funiculus. Fruit indehiscent, commonly drupaceous; seed without perisperm.—Illustrative Genera: Tribe 1. ANACARDIEÆ. Ovary 1-celled. *Rhus*, L.; *Melanorrhea*, Wall.; *Schinus*, L.; *Semecarpus*, L. Tribe 2. SPONDIEÆ. Ovary 2–5-celled. *Spondias*, L.

Affinities, &c.—The prominent differential characters of this order reside in the solitary ovule, with ventral raphe and inferior micropyle, or dorsal raphe if the micropyle be superior. This Order is related to the Xanthoxylaceæ in many respects, but differs in the structure of the ovary and seed. From the Burseraceæ also it is divided by the same characters, although *Spondias* connects them as regards the fruit; while the same peculiarities relate it on the other hand to certain Connaraceæ, Rosaceæ, and Leguminosæ.

Distribution.—A large Order, the species of which are chiefly tropical, diminishing rapidly beyond the tropics.

Qualities and Uses.—The resinous juice of these plants is acrid, or violently irritating and poisonous; it often becomes black in drying. Some kinds, however, yield edible, and even valuable fruits. *Anacardium occidentale*, the Cashew-nut, is remarkable for the curious fleshy enlargement of the peduncle supporting the nut; this peduncle is edible, as is also the seed when roasted; but the pericarp contains acrid volatile oil. A gum-resinous juice exudes from the wood, called Gomme d'Acajou, which is used when fresh as a varnish. *Semecarpus Anacardium*, the Marking-nut, *Melanorrhea usitatissima*, *Stagmaria verniciflua*, *Rhus vernix*, &c. are among the plants furnishing varnishes used in the East Indies, China, and Japan for lacquered ware; their juices are white at first, and become black after exposure to the air. Mastic is obtained from *Pistacia atlantica* and *P. Lentiscus*, Scio turpentine from *P. Terebinthus*; the fruit of *Pistacia vera* is the Pistachio-nut, highly valued in Eastern cookery. *Mangifera indica*, with numerous varieties, yields the well-known tropical drupe called the Mango. The Sumachs, species of *Rhus*, are acrid and poisonous, affecting some constitutions more than others, and sometimes producing violent erysipelas when applied to the skin. *R. Toxicodendron* is the Poison-Oak of North America; *R. venenata*, the Poison-Elder or Poison-Sumach. *R. typhina*, *glabra*, and *Coriaria* have acid fruit and astringent bark, used in tanning; *R. Cotinus* (which is sometimes grown in our shrubberies under the name of the Wig-plant, from the hair-like nature of the sterile flower-stalks) yields the dye-wood called Young Fustic; *R. Metopium*, the Hog-gum of Jamaica, a powerful purgative and emetic. *Spondias purpurea* and *S. Mombin* yield succulent fruits eaten in Brazil and the W. Indies under the name of Hog-plums; *S. Cytherea* or *dulcis* affords a delicious fruit in the Society Islands.

SABIACEÆ are a small Order of East-Indian plants, removed by recent authors from Anacardiaceæ, where they were formerly placed as anomalous forms. They are remarkable for the superposition of the parts of the flower.

CONNARACEÆ form an Order of tropical trees and shrubs, usually placed near Anacardiaceæ, but destitute of resinous juice, and with orthotropous ovules; the fruits are apocarpous and follicular. They are also allied to the Xanthoxylaceæ. The seeds sometimes have an aril; those

of some species of *Omphalobium* are edible. The Zebra-wood, used in cabinet-making, is stated by Schomburgk to be the produce of a Guiana species of this genus, *O. Lamberti*, of great size.

BURSERACEÆ. The Balsam Order consists of trees or shrubs abounding in balsam or resin, with alternate or opposite compound leaves, sometimes stipulate and dotted; flowers perfect, or sometimes diclinous by abortion; calyx persistent, with 2–5 divisions; petals and stamens perigynous, outside a perigynous disk; ovary 1–5-celled, superior, sessile in or upon the disk; ovules in pairs; micropyle superior; raphe ventral; fruit dry, 1–5-celled, often splitting into valves; seeds aperispermic; cotyledons plicate, rarely flat.—Illustrative Genera: *Boswellia*, Roxb.; *Balsamodendron*, Kunth; *Canarium*, L.; *Amyris*, L.

Affinities, &c.—The Burseraceæ (or, as they are sometimes called, Amyridaceæ), excepting the genus *Amyris* itself, have a many-celled fruit, which forms a link between Anacardiaceæ and Aurantiaceæ; but the shell of the fruit is hard here, and opens by valves. *Amyris* has dotted leaves. The ovules in pairs separate them from Anacardiaceæ. The want of scales to the stamens separates them from Simarubeæ. From Rutals they differ in their aperispermic embryo. From Aurantiads they differ in the fruit.

Distribution.—The Order consists of about 150 species, distributed throughout the tropics of Asia, Africa, and America.

Qualities and Uses.—Fragrant resinous juices are the chief characteristics of this Order. *Boswellia thurifera*, *floribunda*, and *glabra* yield the East-Indian Olibanum or Frankincense; *B. papyrifera* (Abyssinia) yields a similar Olibanum, and has a remarkable inner bark, capable of separation into sheets, which are used as paper. *Balsamodendron Myrrha* yields Gum Myrrh; Balm of Mecca is produced by *B. Opobalsamum* and *B. gileadense*. *B. Mukul* yields Googal, or Bdellium; *B. pubescens* another balsam, almost soluble in water. *Amyris hexandra* and *A. Plumieri* yield Elemi; the wood of *A. balsamifera* is known as Lignum Rhodium; the balsam of *A. toxifera* is poisonous. *Icica Icicariba* yields Brazilian Elemi, *I. Carana* American Balm of Gilead; and other species afford similar products. *Elaphrium tomentosum* supplies one of the kinds of Tacamahaca, *E. elemiferum* Mexican Elemi; and *Canarium commune* furnishes East-Indian or Manilla Elemi. *Bursera paniculata* (Mauritius) is called Bois de Colophane, giving out freely when wounded an oily juice smelling like turpentine; *B. gummifera* yields Chibou resin, *B. acuminata* Resin of Carana; *Hedwigia balsamifera*, Beaume à cochon, used as a substitute for Copaiba. The wood of *Icica altissima* is used for canoes in British Guiana, under the name of Cedar-wood.

LEGUMINOSÆ. The Pulse Order.

Series Calyciflorae; *Coh.* Rosales, *Benth. et Hook.*

Diagnosis.—Herbs, shrubs, or trees, with irregular, often papilionaceous or regular flowers; stamens 10 or rarely 5, or sometimes indefinite, diadelphous, monadelphous, or distinct; pistil simple,

free, becoming a legume or lomentum; seeds usually aperispermic; leaves mostly alternate, stipulate, usually compound.

Character.

Thalamus usually flat or convex. *Calyx* more or less deeply 5-fid, the odd lobe in front or next the bract; lobes often unequal and variously combined. *Corolla*: *petals* 5, or 4–0 by suppression, springing from the bottom of the calyx, papilionaceous or regular: the odd petal, when present, posterior (figs. 363, 366). *Stamens* definite or indefinite, springing from the calyx, rarely hypogynous, distinct or coherent in one or two bundles (9 + 1, fig. 367), or rarely in three; *anthers* opening by chinks or by pores. *Ovary* usually solitary, simple, of one carpel (very rarely 2 or 5), 1-celled, 1-, 2-, or many-seeded; *style* and *stigma* simple (fig. 368). *Fruit*: a legume, lomentum, or rarely a drupe; *seeds* attached to the upper (ventral) suture, 1 or many, sometimes with an arillus; embryo without, rarely with perisperm, straight, or with the radicle folded on the cotyledons.

Fig. 362.

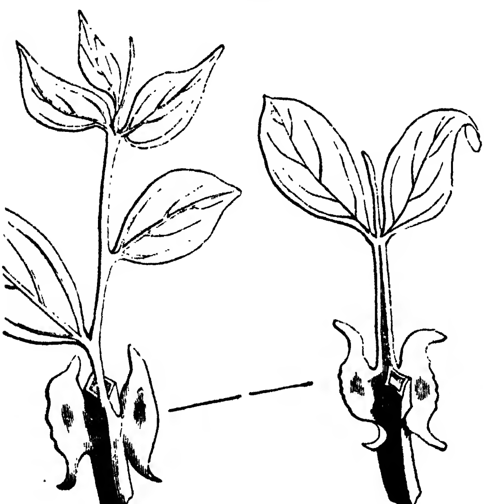


Fig. 363.

Fig. 364.

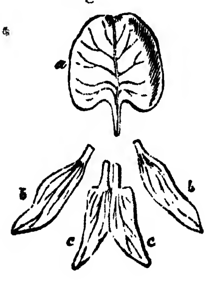


Fig. 362. Compound leaves, terminating in a short tendril, and stipules of Bean (*Vicia*).
Fig. 363. Papilionaceous corolla of Pea.
Fig. 364. The separated petals: *a*, vexillum; *b*, *b*, alæ; *c*, *c*, carina.

Fig. 365.

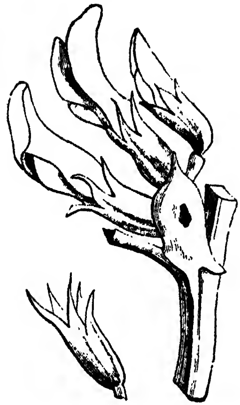


Fig. 366.

Fig. 367.

Fig. 368.

Fig. 365. Inflorescence, calyx, corolla, &c., of Bean.
Fig. 366. Ground-plan of a Papilionaceous flower—the bracket represents the position of the bract, the O that of the axis.
Fig. 367. Diadelphous stamens of Leguminosæ.
Fig. 368. Stipitate ovary, style, and stigma of *Colutea.*

This large Order is divided into three Suborders, which are distinguished by the following characters :—

1. Papilionaceæ. Corolla papilionaceous, imbricated in the bud, with the upper, odd petal, called the standard or "vexillum," exterior.—2. Cæsalpinieæ. Corolla imbricated in æstivation, the odd petal with its edges inside the lateral ones.—3. Mimoseæ. Corolla valvate in æstivation.

The typical floral formula is $|\overline{S}\,5$, P 5, A 5 + 5, G 1, but much variation from it occurs.

This vast Order is further subdivided into several tribes, the subdivisions being founded on the degree of cohesion of the stamens, the nature of the pod and cotyledons, the leaves, habit, &c.

Illustrative Genera.

1. Papilionaceæ.

Chorozema, *Labill.*	Astralagus, *L.*	Phaseolus, *L.*
Lupinus, *L.*	Pisum, *L.*	Dalbergia, *L.*
Lotus, *L.*	Arachis, *L.*	Sophora, *L*
Trifolium, *L.*	Ornithopus. *L.*	Swartzia, *Willd.*

2. Cæsalpinieæ.

Cæsalpinia, *L.*	Tamarindus, *L.*	Ceratonia, *L.*
Cassia, *L.*	Copaifera, *L.*	Sclerolobium.

3. Mimoseæ.

Parkia, *L.*	Mimosa, *L.*	Inga, *Willd.*
Adenanthera, *L.*	Acacia, *Willd.*	Prosopis, *L.*

Affinities, &c.—This immense Order presents very considerable variety of structure within its wide limits; and but one character is absolutely constant, the position of the sepals  The irregularity of the corolla disappears altogether in the *Mimoseæ*, and the legume is exchanged for a drupe in *Detarium* and *Dipteryx*: this causes a near approach to the Rosaceæ; but it may be noticed that when the flower is regular the fruit is leguminous, and *vice versâ*; and the anterior position of the odd sepal of the calyx is an unexceptional character of this Order. The *Cæsalpinieæ* have the papilionaceous exchanged for a spreading irregular form, or the petals are suppressed. In *Mimoseæ* the stamens are hypogynous. The last fact brings the Order closely into relation with the Anacardiaceæ, from which it is not easy to distinguish some of the apetalous *Cæsalpinieæ* at first sight.

The single carpel in the ovary of this Order is almost a universal character; two carpels, however, appear to be normally present in *Diphaca*

Fig. 369.

Fig. 371.

Fig. 372.

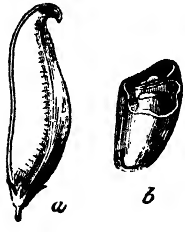


Fig. 370.

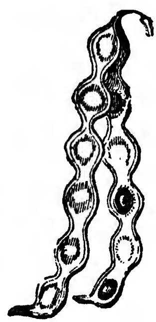


Fig. 369. Legume of *Pisum*.
Fig. 371. Legumes of *Medicago*.
Fig. 370. Lomentum of *Acacia*.
Fig. 372. Legume of *Astragalus*: *a*, entire; *b*, cut across, to show the false partition.

and *Cæsalpinia digyna*; a double ovary sometimes occurs as a monstrosity in *Wistaria sinensis*, in *Gleditschia*, and in the French bean (*Phaseolus*); and a *Mimosa* with 5 carpels (thus a symmetrical flower) is said to have

been seen by St.-Hilaire. The simple legume presents a great variety of conditions, both of form, consistence, and dehiscence. Its normal form is such as we see in the garden Pea (fig. 369); in *Colutea* (the Bladder-Senna) it is inflated and membranous; in *Astragalus* the dorsal suture turns in and forms a false septum (fig. 372); in *Phaca* it is spongy or fleshy; in many cases it is woody; it may be straight or curved, or even spirally curled (*Medicago*, fig. 371); in the lomentaceous form it is constricted at intervals, often breaking into 1-seeded joints (fig. 370); in *Cathartocarpus* it is cylindrical; in *Detarium* and *Dipteryx* the 1-seeded ovary develops a bony endocarp and fleshy epicarp, and becomes a drupe, like the Almond. The dehiscence is equally varied: normally both sutures open and the valves separate; in *Hæmatoxylon* the valves adhere at the sutures and split in the middle. In *Carmichaelia* the valves separate from the suture; in *Ornithopus*, &c. the lomentum breaks up, and the pieces either open or remain indehiscent; in *Entada* the lomentaceous pod is opened by the valves separating in pieces. In *Cathartocarpus*, *Arachis*, *Tamarindus*, and other cases no dehiscence occurs at all; and in *Cathartocarpus* and *Tamarindus* a pulp is formed inside the legume.

The irritability of the leaves of many Leguminous plants is a striking characteristic: it is most remarkable in the *Hedysareæ*, as in *Smithia*, *Desmodium*, &c., and in *Mimoseæ*; but it exists in a lower degree very commonly, even in the Locust-tree (*Robinia Pseudo-acacia*). The Acacias are noticeable for the phyllodial petioles, which often wholly replace the leaves (fig. 373).

Fig. 373.

Phyllode, with xillary head f flowers, of *Acacia*.

Distribution.—The Order comprises nearly 7000 species. The *Papilionaceæ* are universally distributed, but are most abundant in warm climates; some genera are widely diffused, others almost confined to particular parts of the globe, as Australia, North or South America, Cape of Good Hope, &c. The *Cæsalpinieæ* and *Mimoseæ* are chiefly tropical; but the latter abound beyond this limit in Australia. Traces of Leguminous plants have been observed in the Lower Eocene and more recent formations.

Qualities and Uses.—This Order contains a vast number of plants; and among them there is an exceeding diversity of properties. Those with mild juices are frequently exceedingly nutritious; when the juices are more concentrated, they become either purgative or astringent, and some of them poisonous; the poisonous properties occur in all parts, but chiefly in the seeds and bark. In other respects they furnish most valuable timber, fibres, gums, dyes, &c. In enumerating some of the most important plants, it will be best to take them under the heads of the Suborders.

1. *Papilionaceæ.*—A large proportion of the common fodder-plants, such as Clover (*Trifolium*), Lucern and Medic (*Medicago*), *Melilotus*, Sainfoin (*Onobrychis*), &c., belong to this Suborder; and various other similar plants are in use in foreign countries, such as species of *Astragalus*, *Crotalaria juncea*, *Desmodium diffusum*, *Indigofera enneaphylla*, &c. The seeds of many species are eaten, constituting the various kinds of pulse; such as Broad Beans (*Faba*), Haricots and Scarlet-Runner Beans (*Phaseolus*),

Peas (*Pisum, Dolichos*), Lentils, (*Ervum, Vicia*), Chick-peas (*Cicer*), Pigeon-peas (*Cajanus*), Lupines, &c. The roots of some of these are said to be poisonous, as those of *Phaseolus*; but, as is well known, the pericarps or pods are eaten boiled in the young state. Saccharine matter exists in the roots of Liquorice (*Glycyrrhiza glabra*, with *G. echinata* and *glandulifera*); a kind of Manna is obtained from the Camel-thorn (*Alhagi Maurorum*); *Astragalus glycyphyllus* has a sweet juice. The tuberous roots of *Dolichos tuberosus* and *bulbosus, Apios, Pueraria,* and *Lathyrus tuberosus* are eaten in the same way as potatoes.

Among the purgative species are Bladder-Senna (*Colutea arborescens*), the leaflets of which are often used to adulterate true Senna, and *Coronilla Emerus* and *C. varia*: the last is reputed to be poisonous; various species of *Genista, Cytisus* (Broom), *Robinia*, &c. are diuretic and cathartic.

The well-known astringent substance Kino is obtained in Africa from *Pterocarpus erinaceus*, in the East Indies from *P. Marsupium*, Gum Dragon from *P. Draco*, and Red Sandal-wood from *P. santalinus*. A somewhat similar substance to Kino is obtained in the East Indies from the Dakh trees (*Butea frondosa* and *superba*). *Erythrina monosperma* yields Gum Lac. A few plants of this Suborder yield gum, such as Tragacanth, from *Astragalus verus, creticus, cristatus, gummifer*, and *strobiliferus*.

Dyes are obtained from many, as Indigo from *Indigofera tinctoria, cærulea, argentea*, and probably others, and from *Tephrosia Apollinea* and other species; *Baptisia tinctoria* gives an inferior kind. The flowers of the *Buteæ* give a brilliant orange-yellow colour; *Sophora japonica* furnishes yellow from the pulp of its pods; Dyer's broom (*Genista tinctoria*) gives a good yellow colour, and forms a green with *Isatis*. Oil is furnished by the seeds of the Ground-nut (*Arachis hypogæa*) and others.

Ornamental and useful timber is afforded by some, as Rose-wood (*Palissandre* of the French) from various Brazilian species of *Triptolomea*, Itaka-wood of Guiana (*Machærium Schomburgki*), Laburnum-wood (*Cytisus Laburnum*), Locust (*Robinia Pseudo-acacia*); *Dalbergia Sissoo* and other species, and *Pterocarpus dalbergioides*, are highly valued in the East Indies. Others furnish fibrous substances, such as *Crotalaria juncea*, yielding Bengal Hemp.

Dipteryx odorata (Tonka-bean) and *D. oleifera* (Eboe-nut) are used in perfumery. The hairs from the pods of Cowhage (*Mucuna pruriens*) were formerly used as an anthelmintic. The seeds of *Astragalus bæticus* are used as a substitute for and adulteration of coffee in Germany.

The distinctly poisonous plants of this Suborder are numerous. The roots of the Scarlet-runner bean (*Phaseolus multiflorus*) and other species are narcotic poisons; also the seeds of Laburnum (*Cytisus Laburnum, alpinus*, &c.), those of *Lathyrus Aphaca*, and, it is said (but denied by others), those of *Abrus precatorius* (the scarlet seeds with a black patch, often used as beads), *Anagyris fœtida, Ervum Ervilia*, &c. Indigo is a violent poison; the shoots of various kinds of *Tephrosia*, especially *T. toxifera*, are used to poison fish, as is the bark of *Piscidia Erythrina*, a powerful narcotic. Species of *Geoffroya*, as *G. vermifuga* and *spinulosa*, and *Andira inermis* and *retusa*, having drastic purgative and emetic barks, are acrid-narcotic poisons in large doses. *Gompholobium*, an Australian genus, is said to poison sheep. *Physostigma venenosum* furnishes the poisonous Calabar bean used as an ordeal by the natives, and in medicine for its use in contracting the pupil of the eye. It acts as a powerful nervous sedative.

2. *Cæsalpinieæ.*—This Suborder does not appear to have any decidedly poisonous properties; but a purgative quality is very common, as in Senna, *Cassia obovata*, *Senna acutifolia*, and *lanceolata*; *C. marilandica* and other North-American species have similar properties. *Cassia* or *Cathartocarpus Fistula* has a purgative fruit; and the pulp of the Tamarind (*Tamarindus indica*) shares this quality. Besides the Tamarind, other fruits, less acid, are eaten, as the Tamarind Plum (*Dialium indicum*) and the Tamarinds of Sierra Leone, which are species of *Codarium*. Carobs or Algarobs, the legumes of *Ceratonia Siliqua* (also called St. John's, or the Locust-tree), are used for feeding horses in Spain, and have recently been imported for feeding stock in this country. *Gleditschia triacanthos* bears a similar fruit, called in North America the Honey-locust; the fruit of the West-Indian Locust, *Hymenæa Courbaril*, is somewhat similar, but is said to purge when fresh gathered; a kind of beer is made from it by decoction and fermentation.—Many *Cæsalpinieæ* have bitter and astringent properties, and are sometimes used in medicine, several of them in tanning and dyeing, as Divi divi, the pods of *Cæsalpinia Coriaria*, one of the most powerful of known astringents; the bark of some species of *Bauhinia* and *Cassia* are used in similar ways.—The dye-woods are important, namely Logwood (*Hæmatoxylon campechianum*), Brazil-wood or Pernambuco-wood (*Cæsalpinia echinata, brasiliensis*, and other species), Cam-wood or Barwood (*Baphia nitida*), &c. The West-Indian Locust-tree (*Hymenæa Courbaril*), the Purple-heart of Guiana (*Copaifera pubiflora* and *bracteata*), *Melanoxylon Brauena*, *Eperua falcata*, &c. yield very hard and durable timber. The size of some of the Cæsalpineous trees of the South-American forests is said to be enormous, as much as 84 feet in circumference at the base, where large projecting buttresses occur, and 60 feet at the commencement of the clear run of the trunk.

The bark of *Bauhinia racemosa* and *parviflora* is used for cordage in the East Indies. Gum is yielded by several, as by *Bauhinia retusa* and *B. emarginata* in the East Indies, and *Pithecolobium gummiferum* in Brazil. Anime resin is obtained from *Hymenæa Courbaril*; Mexican Copal probably from an allied plant: Brazilian Copal from various species of this genus, and from *Trachylobium Martianum*; Madagascar Copal, and perhaps that of the East Indies in general, from *Hymenæa verrucosa*. Balsam of Copaiba is derived from various West-Indian and Brazilian species of *Copaifera*; Balsam of Peru from *Myroxylon Pereiræ*: Balsam of Tolu from *M. toluiferum*. *Aloëxylum Agallochum* yields one kind of Eagle- or Aloes-wood, the other coming from an *Aquilaria*.

3. *Mimoseæ.*—Mucilaginous juices concreting into gum and astringent properties of the bark are the most striking qualities of this Suborder. Gum Acacia and its varieties are yielded by several species of *Acacia*:—*A. Verek* and *Adansonii* (Gum Senegal) in West Africa, *A. nilotica* and *Seyal* (Gum Arabic) in Nubia, *A. arabica*, *spinosa*, and (*Vachellia*) *Farnesiana* in the East Indies, *A. decurrens*, *mollissima*, and *affinis* in Australia. The bark of most species of *Acacia* is very astringent, and many kinds are used for tanning in India; the pods of *A. nilotica* are used for the same purpose: and the astringent substance called Catechu is obtained by extraction with water from the heart-wood of *Acacia Catechu*. Various species of *Inga*, *Prosopis*, &c. are very astringent. Some East-Indian Acacias yield valuable timber; the legumes of *A. concinna* and the large

seeds of *Entada Pursætha* contain a saponifying substance. Some kinds of *Mimosa* and *Prosopis* are said to have poisonous properties. *Acacia varians*, of Australia, has been called the Poison-tree. It is hardly necessary to add that a great number of plants from all these Suborders are cultivated for the sake of their beautiful flowers.

MORINGACEÆ form a very anomalous group of 3 or 4 species only, marked by the following characters:—Trees with 2–3-pinnate leaves and thin deciduous stipules; flowers irregular, 5-merous; sepals and petals petaloid; stamens 8–10 on a disk in the tube of the calyx, the outer circle sometimes sterile; anthers 1-celled; ovary superior, stalked, 1-celled with 3 parietal many-ovuled placentas; fruit a long 3-valved pod with the seeds in the middle of the valves; seeds without perisperm. The species are natives of Arabia and the East Indies, and have generally been referred to the vicinity of the Leguminosæ, principally on account of their perigynous irregular flowers, pinnate leaves, and pod-like fruits. The structure of the ovary removes them widely from Leguminosæ, on account of the parietal placentation, since, judging from Rosaceæ, the occurrence of additional carpels in Leguminosæ would be accompanied by an apocarpous condition, or at least by axile placentas. *Diphaca* and *Cæsalpinia digyna* (Leguminosæ) are in fact described as having 2 legumes; but the monstrous forms of *Gleditschia* referred to by De Candolle are said to have 2 coalescent carpels. Hence Lindley places this Order in the neighbourhood of Violaceæ, and conceives that it approaches Polygalaceæ. Others place it between Capparids and Resedaceæ, to the former of which orders it is certainly closely allied. The root of *Moringa pterygosperma* is pungent and aromatic, resembling Horse-radish. A gum like Tragacanth exudes from the bark. The seeds are the Ben-nuts; and the oil of Ben was formerly highly esteemed for perfumery, and for lubricating watchwork, on account of its comparative freedom from easily-solidifying fatty ingredients.

ROSACEÆ. THE ROSE ORDER.

Coh. Rosales, *Benth. et Hook.*

Diagnosis.—Herbs, shrubs, or trees usually with alternate, stipulate leaves, regular bisexual or unisexual flowers; numerous (rarely few) distinct stamens springing from the calyx; carpels 1 or many, either quite distinct or coherent, and enclosed in the tube of the receptacle; seeds (anatropous) 1 or few in each ovary, aperispermic; embryo straight, with large and thick cotyledons; leaves alternate, stipulate.

Character.

Thalamus convex, elongated, or concave, forming a tube (calyx-tube, receptacular tube). *Calyx* synsepalous, with 4–5 lobes, the odd lobe posterior, *i. e.* next the axis, when 5; sometimes with an *epicalyx*. *Corolla*: *petals* 5, distinct, emerging from the calyx, rarely absent. *Stamens* definite or indefinite, given off

...... the petals. *Ovaries* apocarpous, 1–2, or 5 or numerous, 1-celled, sometimes combined together in the excavated receptacle (fig. 374) or tube of the calyx; *ovules* 1 or few; *styles* lateral (fig. 377) or terminal. *Fruit*: a drupe, an achene, or a dry or succulent etærio (figs. 375, 376), or a cynarrhodon or a pome (fig. 378); *seeds* 1 or more, aperispermic; *embryo* straight.

Fig. 374.

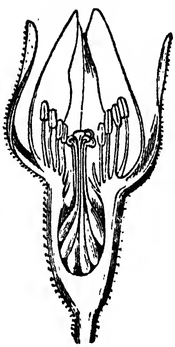


Fig. 375.

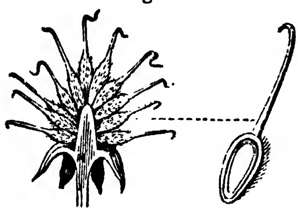


Fig. 378.

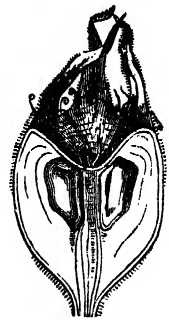


Fig 376.

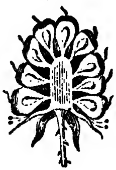


Fig. 377.

Fig. 379.

Fig. 380.

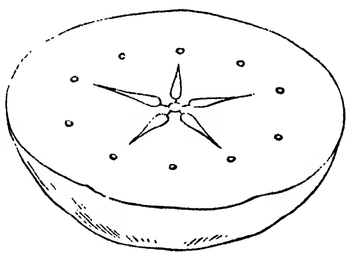


Fig. 374. Section of the flower of *Rosa*, showing the flower-tube enclosing the carpels.
Fig. 375. Dry etærio of *Geum*, with separate carpel in section.
Fig. 376. Section of succulent etærio of *Rubus*.
Fig. 377. Ovary of *Fragaria* with lateral style.
Fig. 378. Section of the pome of *Mespilus*.
Fig. 379. Calyx of the Rose; the numbers indicate the sequence of the sepals from without inwards, or from below upwards.
Fig. 380. Transverse section of pome of Apple, showing the five carpels imbedded in the fleshy flower-tube.

This Order is commonly broken up into several smaller Orders, which we shall characterize here as Suborders.

1. CHRYSOBALANEÆ. Trees or shrubs with free stipules; carpel 1, adherent more or less to one side of the calyx-tube; ovules 2; style basilar; fruit drupaceous; seed erect; radicle inferior.—2. DRUPACEÆ. Trees or shrubs with free stipules; carpel 1, free; style terminal; fruit a drupe, not enclosed in the tube of the flower, which is deciduous; seeds suspended.—3. POMEÆ. Trees or shrubs with free stipules; carpels 1–5, more or less united together and with the sides of the flower-tube; styles terminal; fruit a pome, 1–5-celled or spuriously 10-celled, with a crustaceous *core* or bony *stones* (fig. 375); seeds ascending.—4. ROSEÆ. Shrubs or herbs with adnate stipules; carpels free from the flower-tube, 1 or many, 1-celled, sometimes cohering; styles lateral; fruit usually formed of an assemblage of dry achenes, small drupes, or dehiscent several-seeded follicles; seed suspended, rarely ascending; radicle superior.—5. SANGUISORBÆ. Herbs or undershrubs, apetalous, often diclinous; carpel 1, enclosed in the flower-tube; style from the summit or base; fruit an achene, surrounded by the persistent tube of the flower; seed 1, suspended or ascending.

ILLUSTRATIVE GENERA.

I. CHRYSOBALANEÆ. *Chrysobalanus*, L.—II. AMYGDALEÆ, or DRUPACEÆ. *Prunus*, L.—III. POMEÆ. *Pyrus*, Lindl.—IV. ROSEÆ. 1. ROSIDÆ. Flower-tube fleshy, enclosing the achenes: *Rosa*, Tournef. 2. POTENTILLIDÆ. Flower-tube herbaceous; fruit an etaerio: *Rubus*, L.; *Fragaria*, L.; *Potentilla*, L. 3. SPIRÆIDÆ. Flower-tube herbaceous; fruit a ring of follicles; seeds not winged: *Spiræa*, L. 4. QUILLAIÆ. Flower-tube herbaceous; fruit capsular; seed winged: *Quillaia*, Mol. 5. NEURADEÆ. Flower-tube adhering to a ring of 10 carpels; seed pendulous: *Neurada*, L.—V. SANGUISORBEÆ. *Alchemilla*, Tournef.; *Poterium*, L.

Affinities, &c.—Typical formula |S 5 P 5 A∞ G 1–∞. Closely allied to Leguminosæ; and, indeed, the only constant point of difference consists in the position of the odd sepal—posterior in Rosaceæ, anterior in Leguminosæ. The *Chrysobalaneæ* may be regarded as forming a link between the Leguminosæ and the *Drupaceæ*, touching that Order especially in its drupaceous genera and those with a laterally adherent calyx. The *Drupaceæ* have some affinity also to Anacardiaceæ; *Pomeæ* again connects the Order with the epigynous families, especially Myrtaceæ, through *Punica*. *Roseæ* resemble *Pomeæ* in many respects, but their affinities go out in other directions; Calycanthaceæ should, perhaps, scarcely be separated from them. The *Spiræidæ* very much resemble some Saxifragaceæ (distinguishable by their perispermic seeds); and the *Potentillidæ* remind us of the Ranunculaceæ in the fruit and the adnate stipules, which sometimes closely approach the dilated base of the petiole of *Ranunculus*, &c.; but Ranunculaceæ have perisperm and usually hypogynous stamens, though the difference in some genera between hypogynous and perigynous posi-

tion of the stamens is almost imperceptible. *Sanguisorbeæ* are merely a degraded form of *Roseæ*, where the petals and one or other set of essential organs are abortive in each flower.

Distribution.—There are about a thousand species. The *Chrysobalaneæ* are chiefly found in tropical America and Africa, more rarely in Asia; the *Drupaceæ* are mostly natives of the temperate parts of the Northern Hemisphere, but are widely spread in cultivation; the *Pomeæ* also belong to the Northern Hemisphere; most of the *Roseæ* and *Sanguisorbeæ* belong to temperate and cold climates, but a few are tropical.

Qualities and Uses.—The succulent fruits of many of the plants form the most striking feature of this Order. Various parts of the structure, but especially the seeds, yield much hydrocyanic acid in the Suborders *Drupaceæ* and *Pomeæ*. The bark and root of almost all are bitter and astringent, owing to the presence of tannin. *Drupaceæ* commonly contain a gum (resembling Gum Arabic) in the sap. This gum is the result of a pathological change in the tissues.

Most of the *Chrysobalaneæ* have stone-fruits; that of *C. Icaco* (West Indies) is eaten under the name of Cocoa-plum.

Among the *Drupaceæ* we have the fruits:—Almond (*Amygdalus communis*); the Peach and Nectarine (*A. persica*); the Plum in all its varieties, such as Greengages, Bullaces, Damsons, &c. (*Prunus domestica, spinosa*, and varieties); the Apricot (*Prunus armeniaca*); the Cherry (*Cerasus avium*, &c.). *Cerasus Lauro-cerasus* is the common "Laurel" or Cherry-laurel of our shrubberies, *C. lusitanica* the Portugal Laurel. Many of these plants contain a considerable quantity of *amygdaline*, causing the formation of prussic acid when they are bruised. This gives to the seeds of the Bitter variety of Almond, and to all other seeds in this Suborder, a poisonous property, which exists also to a great extent in the leaves and shoots of the Cherry-laurel, the flowers of the Almond, Peach, &c. The seeds also contain a fixed oil, which may be obtained by expression; and that of the Sweet variety of the Almond is devoid of *amygdaline*, and thus harmless. The bark of *Prunus serotina* is used medicinally in intermittent fevers. *Pomeæ* have succulent fruits, such as the Apple, Pear (*Pyrus Malus* and *communis*), Quince (*Cydonia vulgaris*), Medlar (*Mespilus germanica*), &c., which have been brought into the edible condition by cultivation; when wild, they are mostly austere, like those of the Hawthorn (*Cratægus*), of the Mountain Ash (*Pyrus Aucuparia*), &c. The seeds contain amygdaline, and therefore yield prussic acid; as do also the flowers, bark, and root of the Mountain Ash. Quince-seeds are valuable for the mucilage they contain.

The *Roseæ* yield edible fruits, such as the Raspberry and Blackberry (*Rubus idæus* and *fruticosus*) and the Strawberry (*Fragaria elatior, vesca*, &c.). The petals of Roses yield the essential oil called Otto or Attar of Roses. Kousso (*Brayera anthelmintica*) is used as a vermifuge. Most of the *Roseæ* have astringent bark and roots: some are unwholesome. *Sanguisorbeæ* have astringent properties similar to *Roseæ*. *Quillaiæ* contain in their bark a saponaceous principle, which renders them useful for cleaning silk fabrics.

CALYCANTHACEÆ form a small Order, consisting of shrubs with opposite entire leaves, without stipules; sepals and petals similar and indefinite;

anthers adnate and extrorse; cotyledons convolute; otherwise like Rosaceæ.—The species are natives of North America and Japan, and are chiefly remarkable for the peculiarity of their floral envelopes, the coloured bracts of the peduncle passing insensibly or undistinguishably into the calyx, and this into the corolla; the segments of both spring from a fleshy tube supporting the stamens and surrounding the carpels; convoluted cotyledons are only found in one Rosaceous plant, *Chamæmeles (Pomeæ)*, but are characteristic of Combretaceæ. Calycanths stand between the Rosaceæ and the Myrtaceæ, and have, perhaps, a distant resemblance to Magnoliaceæ, like that of Rosaceæ to Ranunculaceæ. Baillon places them with Monimiads. Their wood is curious, the stem having four false woody axes around the real axis, giving the stem a quadrangular character. The chief property is fragrance of the blossom. *Chimonanthus* produces yellow fragrant flowers upon the leafless branches during the winter. *Calycanthus floridus* has an aromatic bark.

MYRTACEÆ. The Myrtle Order.

Coh. Myrtales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with leaves opposite or alternate, entire, usually dotted, and with a submarginal vein; flowers usually axillary, regular, polypetalous or apetalous; calyx adherent, 4–5-cleft, valvate or imbricate, sometimes falling off like a cap; petals 4–5, imbricated; stamens 8–10 or numerous, rarely 4–5, distinct or polyadelphous; ovary 1-, 2-, 4-, 5-, or 6-celled; style and stigma simple; placentas axile; seeds usually indefinite, aperispermic; fruit dry or succulent, dehiscent or indehiscent.—Illustrative Genera: Tribe 1. Leptospermeæ. Fruit capsular. *Melaleuca*, L.; *Eucalyptus*, Hérit.; *Metrosideros*, R. Br.; *Bæckia*, L. Tribe 2. Myrteæ. Fruit baccate. *Punica*, L.; *Psidium*, L.; *Myrtus*, Tournef.; *Eugenia*, Michel.

Affinities, &c.—This Order is nearly related to the Rosaceæ on the one hand, and to the Melastomaceæ, Lythraceæ, and Onagraceæ on the other. The Lecythidaceæ, the Chamælauciaceæ, and some other smaller Orders mentioned below are often combined with the Myrtaceæ; but as the plants belonging to them are less interesting, or less frequently seen, it is convenient here to exclude them, in order to retain a very definite character for the Myrtaceæ proper. This Order is generally known among epigynous forms by the vein running round within the margin of the simple, entire, and mostly opposite leaves, uniting with the midrib at the end, together with the transparent glandular dots and the absence of stipules and of appendages to the anthers. The fruit of *Punica*, or Pomegranate, is very curious, and presents unusual conditions—a double circle of carpels, which by the mode of growth of the excavated receptacle come to be placed one above another, so as to present two tiers of loculi in the fruit. The real nature of the structure may be conceived by comparing it with the Rose, and by supposing the achenes of the latter to become

enlarged loculi containing pulp. Bentham and Hooker put this genus into Lythraceæ; but its affinities seem rather with Myrtles, of which it forms an anomalous genus.

Distribution.—A large Order, the members of which are distributed throughout tropical and subtropical climates.

Qualities and Uses.—Generally aromatic from the presence of a volatile oil, some astringent, and others yielding gums or saccharine juices. The *Myrteæ* are remarkable for their aromatic properties: thus *Caryophyllus aromaticus* furnishes the Cloves used for spice, consisting of the dried unopened flower-buds; *Eugenia Pimenta* and *E. acris*, Allspice or Pimento, consisting of the dried fruits: the buds and berries of the common Myrtle were used in a similar manner by the ancients. This tribe also affords excellent fruits: the Guavas are yielded by species of *Psidium*, chiefly *pomiferum* and *pyriferum*; the Rose-apples by *Eugenia malaccensis*, *Jambos*, *aquea*, &c.; the Pomegranate, *Punica Granatum*, the rind of which is also valuable for its astringent properties, which cause it to be used both medicinally and for tanning. Among the *Leptospermeæ*, the Cajeput, (*Melaleuca Cajeputi*) is well known for its acrid volatile oil, obtained by distillation from the leaves. *Metrosideros* is a genus some of the species of which form very striking features in the vegetation of New Zealand, *M. buxifolia* and other species, called Aki, Rata, &c., overgrowing trees, like the *Ficus indica*, and themselves ultimately becoming exceedingly hard-wooded trees. The *Eucalypti* of Australia are still more remarkable in many respects: some of them attain a height of 200 feet or more, and a diameter of 10 to 15, rising to 100 or 150 feet clear of branches. The bark of some of them separate in fibrous layers, whence they have derived the common name of Stringy-barks. They are also called Gum-trees, from containing a gummy or saccharine sap, occasionally of astringent character. *E. robusta* secretes a red gum in the interior of the trunk; from *E. mannifera* a saccharine substance like manna is obtained. *E. Gunnii* yields, when tapped, a sweet fluid, which is fermented into a kind of beer. *E. resinifera* furnishes an astringent substance known as Botany-Bay Kino. Other species also contain a sufficient quantity of tannin to be of commercial importance. From their rapid growth they have been introduced with good effect in marshy swamps and in dry hills denuded of trees in the South of Europe. The leaves of some species of *Leptospermum* and *Melaleuca* are used for Tea in the Australian colonies.

Many of the Myrtaceæ are cultivated on account of their beauty. The common Myrtle, a native of Persia, naturalized in Southern Europe, bears our winters, and flowers out of doors in the south-west of England. It affords many beautiful varieties in cultivation. The species of *Metrosideros*, *Callistemon*, &c., sometimes called Bottle-brush plants, have very curious and showy blossoms. The Pomegranate flowers and fruits in sheltered places, and bears a very brilliant blossom.

LECYTHIDACEÆ are chiefly distinguished from the Myrtaceæ (with which they are united by Bentham) by the dotless foliage and the hood-like petaloid plate, consisting of concrete stamens, covering the middle of the flower.—The species are usually large trees; their fruit is very remarkable, consisting of a large woody case, the top of which sometimes separates like a lid (*Lecythis*), whence they have been called Monkey-

pots. They are chiefly found in Guiana and Brazil. The Brazil-nuts of commerce are the seeds of *Bertholletia excelsa,* and are formed inside a large round woody seed-vessel. *Couroupita guianensis,* the Cannon-ball tree, yields a fruit containing a pulp agreeable when fresh; the shells, like the "pots" of *Lecythis,* are used for domestic purposes. The bark of *Lecythis Ollaria* and other species is separable into fine papery layers, used for wrapping cigars. *L. Ollaria* is one of the giants of the Brazilian forests; its seeds are called Sapucaya-nuts.

BARRINGTONIACEÆ are a small Order of tropical trees and shrubs, placed by most authors among or near the Myrtaceæ: their foliage agrees rather with that of Lecythidaceæ, although without stipules; but their flowers are destitute of the hood. The structure of their seeds has been misunderstood: they are destitute of perisperm, and consist chiefly of a large axis with minute cotyledons. They appear to have dangerous qualities. Humboldt and Bonpland relate that when the fruit of *Gustavia speciosa* is eaten by children their skin becomes yellow, but the discoloration disappears in a day or two without any treatment. *Barringtonia* and *Gustavia* are met with in cultivation as large and showy stove-shrubs.

AUCIACEÆ are a group of Australian shrubs, of heath-like aspect, distinguished from Myrtaceæ proper chiefly by the fringe of scales or bristles which frequently surrounds the tube of the calyx (whence the name of Fringe-myrtles), and by the 1-celled (rarely 2-seeded) ovary. They have no known utility.—Illustrative Genera: *Chamælaucium,* Desf.; *Darwinia,* Rudge; *Calytrix,* Labill.—Some of the species are very ornamental as greenhouse plants, as the *Darwinias* (*Hedaroma*) &c.

BELVISIACEÆ consist of a few species of handsome shrubs, belonging to the genera *Napoleona,* Palis., and *Asteranthos,* Desf., formerly supposed to be related to Cucurbitaceæ and Passifloraceæ, but apparently only forms of Myrtaceæ remarkable for the several concentric gamopetalous circles of the corolla (or corona), the polyadelphous stamens, and flat stigma. *Napoleona imperialis* forms a large fruit, with an edible pulp and a rind containing much tannin. The structure of the flower is curious and interesting. They are natives of tropical Africa and Brazil.

RHIZOPHORACEÆ (MANGROVES) are trees or shrubs growing on muddy sea-shores, with opposite leaves and deciduous convolute interpetiolar stipules; flowers with an adherent calyx, 4–12-lobed, the lobes sometimes coherent, valvate; petals equal to the calyx-lobes in number, springing from the calyx; stamens perigynous, twice or thrice as many as the petals; ovary 2-, 3-, or 4-celled, each cell with 2 or more pendulous ovules; fruit 1-seeded, crowned by the calyx; seeds aperispermic, germinating and forming a very long root before the fruit falls from the tree. (See fig. 9, p. 18.)—Illustrative Genera: *Rhizophora,* Lam.; *Bruguiera,* Lam.

Affinities, &c.—This small but interesting Order consists of about 20 species, of very distinct habit, but somewhat complicated in their affinities, agreeing with the Myrtaceæ, Melastomaceæ, Vochysiaceæ, and Combretaceæ in many respects, while there is a relation with Lythraceæ, Cunoniaceæ, &c. in others; Endlicher, as well as Bentham and Hooker,

place here *Cassipourea* and *Legnotis*, which connect this Order with the last two; Lindley refers the *Cassipoureæ* or *Legnotideæ* to the Loganial Alliance. The striking feature of this Order is the germination of the seeds within the fruit while attached to the branch, the roots descending to the mud and establishing themselves before the plumule emerges. The trees also continually send out arching adventitious roots, which strike and become new trunks, like those of the *Ficus indica*, forming the Mangrove-swamps of tropical estuaries. The fruit of *Rhizophora Mangle* is edible. The bark is generally very astringent in this family. The wood of the radicles contains curiously branched wood- or liber-cells.

VOCHYSIACEÆ are trees or shrubs, with resinous juice and mostly opposite entire leaves, with glands or stipules at the base; flowers perfect, irregular; calyx and corolla imbricated, of unequal pieces; stamens 1–5, usually opposite the petals, arising from the bottom of the calyx, mostly only one fertile, with an ovate 4-celled anther; ovary free, or partly adherent, 3-celled, with axile placentas, or 1-celled with 2 basilar ovules; seeds usually winged, without perisperm.—Illustrative Genera: *Qualea*, Aubl.; *Vochysia*, Juss.; *Salvertia*, St.-Hil.—The members of this small Order are natives of the equinoctial regions of America, and are known chiefly as timber-trees, often having large showy blossoms. Their affinities are obscure. Some authors regard them as related to the Clusiaceæ, others to the Violaceæ and the Polygalaceæ, near which latter they are placed by Bentham and Hooker. On account of their calyciflorous structure they are usually placed near Combretaceæ.

COMBRETACEÆ are trees or shrubs, with alternate or opposite, exstipulate leaves, not dotted; flowers perfect or diclinous by abortion; calyx adherent, with a 4–5-lobed deciduous limb; petals 5, perigynous, or absent; stamens perigynous, 5, 10, or 15, mostly 10; ovary 1-celled, with 2–4 pendulous ovules; style and stigma simple; seeds aperispermic; cotyledons convolute.—Illustrative Genera: Tribe 1. TERMINALIEÆ. Usually apetalous; cotyledons convolute. *Bucida*, L.; *Terminalia*, L.; *Pentaptera*, Roxb. Tribe 2. COMBRETEÆ. Corolla present; cotyledons plaited. *Combretum*, Löffl.; *Quisqualis*, Rumph. Tribe 3. GYROCARPEÆ. Apetalous; cotyledons convolute; anthers bursting by recurved valves. *Gyrocarpus*, Jacq.; *Illigera*, Bl.

Affinities, &c.—Related to Myrtaceæ, especially through *Punica*, but distinguished by the unilocular ovary and 1-seeded fruit. The structure of the flower allies the Order to Onagraceæ and Rhizophoraceæ; the apetalous forms approximate in some degree to Santalaceæ and Lauraceæ.

Distribution.—An Order comprising upwards of 200 species, generally distributed throughout the tropics.

Qualities and Uses.—The general property is astringency. The barks of *Bucida Buceras*, of *Conocarpus racemosa*, and of various *Terminaliæ* are used for tanning. The fruit of *Terminalia belerica*, the Myrobalan, is astringent. A gum is obtained from the bark of *T. belerica* and *Combretum alternifolium*. *T. Benzoin* has milky juice, which hardens into fragrant gum-resin, used as incense in Mauritius. The seeds of *T. Catappa* are eaten like almonds. Many of the plants are valuable timber-trees; and a number are cultivated on account of their flowers.

ALANGIACEÆ are a small Order of exotic plants, timber-trees, or shrubs, allied to Combretaceæ, but having perispermic seeds with large leafy cotyledons, and there are differences in the corolla and stamens. Lindley considers the plants related in some degree to Myrtaceæ, Melastomaceæ, and Onagraceæ, but, with Endlicher, thinks that, after Combretaceæ, their nearest relatives are probably Cornaceæ and Hamamelidaceæ; Bentham and Hooker group them with Cornaceæ. The succulent fruits are edible, but the plants on the whole are of little importance.—Genera: *Alangium*, L.; *Marlea*, Roxb.; *Nyssa*, Gronov., &c.

MELASTOMACEÆ.

Coh. Myrtales, *Benth. et Hook.*

Diagnosis.—Myrtle-like plants, with opposite curved-ribbed leaves, showy flowers, definite stamens with remarkable appendaged anthers, bursting by pores at the apex. Seeds very numerous, minute, aperispermic.—Illustrative Genera: *Centradenia*, Don; *Melastoma*, L.; *Rhexia*, Nutt.; *Medinilla*, Gaudich.; *Miconia*, DC.; *Mouriria*, Juss.

Affinities, &c.—A large proportion of these plants are distinguishable at first sight by the several large curved ribs running from the base to the apex of the leaves; but this character does not hold in *Memecylon* or in *Mouriria*. In *Memecyleæ*, also, the usually flat cotyledons are convoluted, as in Combretaceæ and exceptional Myrtaceæ; *Mouriria* has the ribs of the leaves inconspicuous. The most striking character of the flower lies in the stamens with their oddly beaked anthers. But the Order differs from the Myrtaceæ also in the contorted æstivation of the corolla. On the other hand, they are allied to the *Lagerstræmieæ* among the Lythraceæ, from which, however, the imbricate or twisted æstivation of the calyx and the characters above noted sufficiently distinguish them. The characters by which the genera are distinguished are the capsular or baccate fruit, the position of the placentas, and the peculiar form of the stamens.

Distribution.—A large Order, the species of which are generally diffused within the tropics—a few also in North America, China, Australia, and N. India.

Qualities and Uses.—The members of this large Order seem to be harmless; and the prevailing character is slight astringency. Many yield edible succulent fruits; the name of *Melastoma* is derived from the fruit staining the mouth black. The most striking peculiarities about the Order are the beauty of the flowers and the curious ribbed appearance of the foliage. A large number of species are cultivated in this country, some as ornamental-foliage plants, others for the sake of their flowers.

ONAGRACEÆ. THE EVENING-PRIMROSE ORDER.

Coh. Myrtales, *Benth. et Hook.*

Diagnosis.—Herbs or shrubs, with 4-merous (sometimes 2–3-merous) flowers; the tube of the calyx (of the receptacle) adhering to the

2-4-celled ovary, calyx-teeth valvate in the bud, or obsolete; the epigynous petals convolute; stamens as many, or twice as many, as the petals, and inserted with them; ovary 2-4-celled; styles united; stigma capitate or 4-lobed; fruit capsular or succulent, with 2-4 cells; seeds numerous, without perisperm.—Illustrative Genera: *Œnothera*, L.; *Clarkia*, Pursh.; *Epilobium*, L.; *Fuchsia*, Plum.; *Circæa*, Tournef.; *Trapa*, L.

Affinities, &c.—Onagrads are allied to Halorageæ, but differ in their often coloured calyx, absence of perisperm, and simple style, from *Trapa* in their convolute imbricate corolla, from Combretaceæ by their plurilocular ovary. The parts of the flower in this Order are sometimes 2-merous, as in *Circæa*, while in *Lopezia* only one stamen exists. Sometimes the petals are absent; and occasionally the flowers are unisexual. *Trapa* is a genus of water-plants sometimes placed with Haloragaceæ, from which, however, its single style and aperispermic embryo separate it. The floating leaves are flat, wedge-shaped, and entire, while the submerged ones are cut up into numerous very fine segments. The germination of *Trapa* resembles that of some endogenous plants.

Distribution.—The Order consists of a considerable number of species, natives chiefly of temperate Europe, North America, and India.

Qualities and Uses.—Harmless, sometimes slightly astringent. The berries of some Fuchsias are edible. They are best known by the numerous garden plants belonging to the Order, most of which are very showy. *Epilobium* has many native species, which are mostly weeds. *E. angustifolium*, however, and *E. hirsutum* are tall and handsome plants. Some of the *Œnotheræ* are called Evening-Primroses, from the yellow flowers opening in the evening. *Trapa* produces a large horned fruit with amygdaloid seeds with unequal cotyledons. *T. natans* is the Water-chestnut of the French. The seeds of *T. bispinosa*, the Singhara-nut (Kashmir), and *T. bicornis* (China) furnish important articles of food.

HALORAGACEÆ are aquatic plants, with small axillary 2-4-merous flowers, often imperfect; calyx adherent, its teeth obsolete; petals often wanting; stamens 1-8; fruit indehiscent, 1-4-celled, with a solitary suspended seed in each cell; perisperm fleshy.—Illustrative Genera: *Hippuris*, L.; *Myriophyllum*, Vaill.; *Haloragis*, Forst.—They are distinguished from Onagraceæ by the reduced calyx and the solitary pendulous and perispermic seeds; the corolla is absent from *Hippuris* and *Proserpinaca*. The former genus has a very simple flower, consisting merely of an adherent calyx with a very short limb, an ovary of one carpel, and a single stamen. The whorled foliage of *Hippuris* and *Myriophyllum* is curious, giving the first the appearance of an *Equisetum*, while the latter are like some of the branched freshwater Algæ. Most of the Order are aquatic; but *Haloragis* and *Loudonia* are terrestrial and more or less shrubby. They are universally diffused, but of little importance.

LYTHRACEÆ. The Loosestrife Order.

Diagnosis.—Herbs, shrubs, or trees, with mostly opposite entire leaves; no stipules; the calyx enclosing, but free from, the 1-4-celled, many-

seeded ovary and membranous pod, and bearing the 4–7 deciduous corrugated petals and 4–14 stamens in its throat, calyx-lobes valvate, the stamens lower down; style 1; stigma capitate, or rarely 2-lobed; capsule enclosed in the calyx, dehiscent; seeds numerous, aperispermic.—Illustrative Genera: *Peplis*, L.; *Ammannia*, Houst.; *Lythrum*, L.; *Cuphea*, Jacq.; *Lawsonia*, L.; *Lagerstrœmia*, L.

Affinities, &c.—In habit, as also in the striated calyx, these plants have some slight resemblance to Labiatæ; but their nearest relations are with several Calycifloral Orders (from which, as Onagraceæ and Melastomaceæ, they differ most strikingly in the superior position of the ovary) and with Saxifragaceæ. From Rhizophoreæ they differ in their want of stipules and in their numerous ovules. From Myrtles, besides the above characters, they may be distinguished by their valvate calyx.

Distribution.—A considerable Order, the members of which are generally diffused, the tribe *Lagerstrœmieæ* tropical. *Lythrum Salicaria*, a common British plant, is remarkable for being found as the only representative of the Order in Australia. Its flowers are, according to Darwin, trimorphic, the stamens and styles being of three different lengths; two of these forms coexist in the same flower, and have different sexual functions.

Qualities and Uses.—Many of the plants have astringent properties; several are valuable as dyes. *Lawsonia inermis* is the celebrated Hennah or Henné of the East, used by women to dye their finger-nails, hands, or feet of a brown-orange colour; it is also used for dyeing Morocco-leather. The flowers of *Grislea tomentosa* are also used for dyeing in India. *Ammannia vesicatoria* is acrid, and has blistering properties. *Physocalymma floribunda*, a Brazilian tree, has a beautiful rose-coloured wood. *Cuphea* contains many favourite cultivated species. Bentham and Hooker place *Punica* (the Pomegranate) in this Order; but it would seem to belong more nearly to the Myrtles.

SAXIFRAGACEÆ. Saxifrages.

Diagnosis.—Herbs, shrubs, or trees, with the pistils mostly fewer than the petals or divisions of the calyx (usually 2, coherent below, and separate or separating above; the petals sometimes wanting), with the (mostly 4–10) stamens springing from the calyx, which is either free or more or less adherent to the 1–4-celled ovary (fig. 381).

Fig. 381.

Section of the flower of Saxifraga.

Character.

Thalamus concave, more or less adherent to the ovaries. *Calyx* 5-parted, more rarely 3-, 4-, or 10-parted, more or less adherent to the ovary. *Corolla*: *petals* imbricate, perigynous, equal in number to the segments of the calyx, and alternate with them, rarely absent. *Stamens* inserted with the petals, equal in number to them and alternate, twice as many, or indefinite. *Ovary* mostly of

2 **carpels, more rarely of 3 or 4 or 5, more or less united into a 2- or more-celled ovary, usually half or wholly inferior; placentas axile; *styles* as many as the cells of the ovary; more or less coherent. *Fruit* usually capsular, dehiscent: *seeds* mostly numerous, small, with fleshy perisperm.**

This extensive group of plants is divisible into four Suborders, which are by some authors regarded as distinct orders:—

1. SAXIFRAGEÆ. Herbs: stipules absent or adnate; petals imbricated, or rarely convolute in the bud; calyx free, or partly adherent, ovary 1–3-celled.—2. ESCALLONIEÆ. Shrubs with alternate simple glandular leaves and no stipules; calyx imbricated in the bud.—3. PHILADELPHEÆ or HYDRANGEÆ. Shrubs with opposite simple leaves and no stipules; calyx valvate; stamens epigynous.—4. CUNONIEÆ. Trees or shrubs with opposite or whorled, simple or compound leaves, and large interpetiolar stipules; petals never valvate.

ILLUSTRATIVE GENERA.

Suborder 1. SAXIFRAGEÆ.
Saxifraga, *L.*
Astilbe.

Suborder 2. ESCALLONIEÆ.
Escallonia, *Mutis.*

Suborder 3. PHILADELPHEÆ.
Philadelphus, *L.*
Deutzia, *Thunb.*
Hydrangea, *L.*

Suborder 4. CUNONIEÆ.
Cunonia, L.

Affinities, &c.—The typical floral formula is | $\widehat{S5}$ P 5 A 5+5 $\widehat{G2}$. The relations of this Order are somewhat complicated, in consequence of the variety of conditions existing among the genera. The herbaceous *Saxifrageæ* are related to the Crassulaceæ in several respects, but differ in habit and in the absence of hypogynous glands—and also to the Rosaceæ, through *Spiræa*, *Astilbe*, &c.; from these, *Deutzia* leads to the shrubby forms, where *Philadelphus* manifestly approaches the Myrtaceæ, while the inflorescence of *Hydrangea* is like that of some Caprifoliaceæ. The *Cunonieæ* are scarcely distinguished, except by habit, from the *Saxifrageæ*; the *Escallonieæ*, passing off from the *Philadelpheæ*, are related to Ribesiaceæ, and more distantly to those Ericaceæ with an inferior ovary. Bruniaceæ differ in their dicoccous fruit; Saxifragaceæ are closely allied to Lythraceæ, but in the latter the embryo is aperispermic. *Parnassia* is referred here by Hooker, but seems more closely to resemble Hypericaceæ or Sauvagesiaceæ. The Australian Pitcher-plant (*Cephalotus follicularis*), the leaves of which are tubular, with a lid closing the tube, belongs to a genus closely allied to Saxifrages, especially to the apetalous ones. From Rosaceæ it differs in the presence of perisperm in the seed. By Bentham and Hooker the following tribes are included in this Order:—Saxifrageæ, Francoeæ, Hydrangeæ, Escallonieæ, Cunonieæ, and Ribesieæ.

Distribution.—A large group; the *Saxifrageæ* are northern and alpine plants; the *Escallonieæ* are chiefly mountain plants of South America; the *Philadelpheæ* belong to South Europe and the temperate regions of

Asia and America; the *Cunonieæ* occur in the East Indies, the Cape, Australia, and South America.

Qualities and Uses.—No important properties are attributed to this Order; a certain degree of astringency prevails in *Saxifrageæ* and *Cunonieæ*. Their chief merit consists in the beauty of the many cultivated species of alpine herbs, and of the hardy and half-hardy flowering shrubs. The Saxifrages, *Deutzia*, *Heuchera*, and *Escallonia*, *Hydrangea*, and others are familiar to every one. *Philadelphus coronarius*, the "Syringa" or Mock-Orange of our shrubberies, a native of the south of Europe, is remarkable both for the beautiful flowers (the sweet perfume of which depends on the presence of an essential oil) and the peculiar flavour of the foliage, resembling that of the cucumber.

FRANCOACEÆ is an Order composed of Chilian herbs with the habit of Saxifrages, and flowers 4-merous throughout calyx, corolla, stamens (in several circles), and carpels. Some authors consider them nearest to Saxifragaceæ, with which they are combined by Bentham and Hooker; others to Crassulaceæ, others to Rosaceæ; Lindley believes their nearest affinity is to Droseraceæ.—Genera: *Francoa*, Cav.; *Tetilla*, DC.

CRASSULACEÆ. THE STONE-CROP ORDER.

Diagnosis.—Succulent herbs or low shrubs with perfectly symmetrical flowers, the petals and pistils equalling the sepals in number (3–20), and the stamens as many or twice as many: perisperm fleshy or none.

Character.

Thalamus mostly flat. *Calyx* free, mostly 5-parted, rarely 3–10-parted, imbricated in the bud, persistent. *Corolla*: *petals* as many as the lobes of the calyx and alternate with them, distinct or united below, emerging from the bottom of the calyx, imbricated in æstivation. *Stamens* as many as the petals and alternate with them, or twice as many (in 2 circles), free or adherent to the (coherent) petals. *Ovaries*: *carpels* in a circle, as many as the petals and opposite to them, often with a glandular scale at the base outside, distinct or more or less coherent; placentas at the ventral suture; *styles* distinct; *stigmas* on the inside. *Fruit*: a circle of dry follicles, or a capsule bursting at the dorsal sutures or by the separation of the walls as valves from the septa; *seeds* varying in number, very small; embryo in the axis of fleshy perisperm.

ILLUSTRATIVE GENERA.

Suborder 1. CRASSULEÆ. *Fruits follicular.*

Tillæa, *Mich.*
Crassula, *Haw.*
Bryophyllum, *Salisb.*
Cotyledon, *DC.*
Sedum, *L.*
Sempervivum, *L.*

Suborder 2. DIAMORPHEÆ. *Carpels coherent into a plurilocular capsule.*

Diamorpha, *Nutt.*
Penthorum, *L.*

Affinities, &c.—The floral formula is S 5 P 5 A 5+5 G 5. This Order is nearly related to the Saxifragaceæ, especially by the genera with capsular fruit; and on the other hand to Paronychiaceæ and Caryophyllaceæ. They are remarkable for their succulent foliage, possessed of a power of subsisting almost entirely on atmospheric elements, and resisting obstinately the influence of heat and drought. They are exceedingly tenacious of life; and *Bryophyllum* is celebrated for the aptitude of its leaves to produce adventitious buds when separated and placed in favourable circumstances. The symmetrical construction of the flowers is likewise interesting to the botanist, and has been dwelt on in the Morphological Part of this work. The Houseleek, *Sempervivum tectorum*, occasionally produces monstrous anthers, with ovules in place of pollen.

Distribution.—Generally found in extratropical regions, in very dry situations, and especially abundant at the Cape of Good Hope.

Qualities and Uses.—Their properties are mostly unimportant. *Sedum acre*, the common yellow Biting Stone-crop of our walls, is so called from its acridity, and is said to be emetic and purgative. Some are eaten; others used as refrigerants. *Cotyledon Umbilicus* has been used in epilepsy.

PARONYCHIACEÆ OR ILLECEBRACEÆ are herbs or shrubs with mostly opposite leaves and often scarious stipules, minute flowers, with 5- or more, rarely 3- or 4-merous calyx; petals small or absent; stamens on the calyx, 1–10; ovary 1-, rarely 3-celled; ovules numerous on a free central placenta, or solitary on a long funiculus from the base of the ovary. Seeds perispermic; embryo curved.

ILLUSTRATIVE GENERA.

Suborder 1. PARONYCHIEÆ. *With scarious stipules; stamens superposed to the sepals.*

Paronychia, *Juss.*
Illecebrum, *Gærtn. f.*
Spergula, *L.*

Subord. 2. SCLERANTHEÆ. *Without stipules; calyx with an indurated tube; petals none; stamens superposed to the sepals.*

Scleranthus, *L.*

Suborder 3. MOLLUGINEÆ. *Stamens alternate with the sepals when equal; if fewer, alternate with the carpels.*

Mollugo, *L.*

Affinities, &c.—This Order consists of upwards of a hundred species, and may be regarded as a degeneration of Caryophyllaceæ, from which they differ in the possession of stipules, the thin petals &c. forming a transition to the apetalous Chenopodiaceæ and Amaranthaceæ. They are also nearly related to Portulacaceæ, differing from some of the genera of that Order only by the position of the stamens opposite the sepals. Some of them are succulent, like the Crassulaceæ, but are distinguished by the structure of the ovary. By Bentham and Hooker they are included in the Chenopodal cohort of the Apetalæ. They are mostly valueless weeds, abounding in barren sandy tracts throughout the temperate regions of the globe.

PORTULACACEÆ are herbs with succulent leaves and regular unsymmetrical flowers (sepals fewer than the petals); sepals 2, rarely 3 or 5; petals mostly 5 or 0; stamens variable. Capsule 1–5-celled, with few or many seeds on long funiculi from the base, or on a free central placenta; embryo curved; round floury perisperm.—Illustrative Genera: *Tetragonia*, L.; *Aizoon*, L.; *Portulaca*, Tournef.; *Talinum*, Adans.; *Claytonia*, L.; *Montia*, Michel.

Affinities, &c.—This Order, as here regarded, has various relations, and is not well defined. It approaches very closely to Caryophyllaceæ through Paronychiaceæ, but may be distinguished by the 2-parted calyx and the number and position of the stamens. Like Paronychiaceæ, the members of this Order are nearly related to the proper apetalous Orders, Chenopodiaceæ &c. Lindley separates the *Tetragonieæ*, *Aizoideæ*, and *Sesuvieæ* in an Order called Tetragoniaceæ, differing from Portulacaceæ in their apetalous flowers, multilocular ovary, and distinctly perigynous stamens. Portulacaceæ would thus be defined chiefly by a 2-sepalous calyx, hypogynous or rarely perigynous stamens, and 1-celled ovary. Bentham and Hooker refer the Tetragonieæ to Mesembryanthaceæ, from which they differ in their apetalous flowers. *Portulaca* is exceptional in its partially inferior ovary and perigynous stamens; hence the Order, as a whole, is considered by Bentham and Hooker to belong rather to the Thalamifloræ than to the Calycifloræ. The plants of this Order are generally diffused, in waste, dry places. *Portulaca oleracea*, Purslane, is an old-fashioned pot-herb; others are used in the same way. *Tetragonia expansa* furnishes New-Zealand Spinach. *Claytonia tuberosa* has an edible tuber. Many have showy but ephemeral flowers. *Lewisia rediviva* (Oregon) has a starchy root, used as food under the names of spatulum or spætlum and *racine amère*; it is pungent and aromatic when raw.

MESEMBRYANTHACEÆ or FICOIDEÆ are shrubby or succulent herbaceous plants, with opposite simple leaves; sepals definite; petals very numerous; stamens indefinite, perigynous; ovary inferior or almost superior, many-celled or 1-celled; ovules numerous, attached by cords to a free central placenta or to axile placentas, or to parietal placentas spreading over the back of each cell; seeds numerous: embryo curved or spiral, on the outside of mealy perisperm.—Illustrative Genus: *Mesembryanthemum*, L.

Affinities, &c.—These plants are very nearly related to Portulacaceæ and Paronychiaceæ. From the former they differ in the parietal, not free central placenta, from the latter in the position of the stamens, many-celled ovary, and dehiscence of the capsule. The structure of the ovary is curious, presenting very different conditions in different members of the Order; probably it is somewhat analogous to that of Cucurbitaceæ, and the diverse positions of the placentas depend on the degree of involution of the carpels and the disruption of the septa. The parietal placenta, together with the presence of numerous petals, serve to indicate a relationship to Cactaceæ. Bentham and Hooker refer to this Order *Tetra-* (see Portulacaceæ) and *Mollugineæ* (see Paronychiaceæ). The plants are remarkable for their succulent foliage, accompanied sometimes by water-vesicles or pseudo-glands on the epidermis, whence the name of Ice-plant applied to *Mesembryanthemum crystallinum*. The ripe capsules

are very hygrometric, the valves opening when wet and closing when dry. It is a rather large Order, of which the majority belong to the sandy tracts of the Cape, but a few are found in South Europe, America, China, and the South Seas. The foliage of *M. edule* (Hottentots' fig) is eaten at the Cape; *M. emarcidum* acquires narcotic properties when fermented. Several are burnt for the soda-ash in Egypt, Spain, &c. The seeds of some yield a kind of flour.

PAPAYACEÆ are trees or shrubs, sometimes with an acrid milky juice, alternate, lobed, long-stalked leaves, and diclinous, sometimes hermaphrodite, dichlamydeous flowers. Male fl.:—calyx free, minute, with 5 teeth; corolla sympetalous, with 5 lobes; stamens definite, epipetalous. Female fl.:—Petals 5; corona filamentous or fimbriate, sometimes none; ovary free, 1-celled, with 3–5 many-seeded parietal placentas; fruit succulent or dehiscent; embryo in the axis of fleshy perisperm.—Illustrative Genera: *Carica*, L.; *Modecca*, L.; *Ceratosicyos*, Nees.—The present Order stands near to Cucurbitaceæ and to Passifloraceæ, differing, however, in important respects from both,—since the former have an inferior ovary and aperispermic seeds; the latter, hermaphrodite flowers and a characteristic coronet arising from the tube of the flower, of a different nature to the staminodes or sterile stamens of the present group. Bentham and Hooker include it under Passifloraceæ.—The Papaw-tree, *Carica Papaya*, has a succulent fruit, edible when cooked, but the juice of the unripe fruit and the seeds appear to be very acrid. *C. digitata* (Brazil) is regarded as a deadly poison, and its juice blisters the skin. The species of *Carica* are natives of South America, the other genera are East-Indian or African.

PANGIACEÆ are an Order of arborescent plants closely related to Papayaceæ, differing chiefly in being polypetalous, and by the female flowers having scales in the throat; the number of parts in the floral circles also appears more variable. They constitute a Tribe of Bixaceæ in the 'Genera Plantarum' of Bentham and Hooker.—They are poisonous plants found in the hotter parts of India. *Hydnocarpus venenatus* is a native of Ceylon; its fruit produces dangerous intoxication. The seeds of *Pangium* are sometimes used, after boiling and extraction with water, as a spice, but even then have cathartic properties.—Genera: *Pangium*, Reinw.; *Gymnocarpea*, R. Br.; *Hydnocarpus*, Gærtn.

PASSIFLORACEÆ. PASSION-FLOWERS.

Coh. Passiflorales, *Benth. et Hook.*

Diagnosis.—Climbing plants, rarely erect trees, with tendrils and foliaceous stipules; leaves and leaf-stalks often glandular; flowers perfect; calyx 5-parted, with numerous filamentous processes springing from the tube of the flower (receptacle), inside the 5 petals; stamens 5, monadelphous, adherent to the stalk of the 1-celled ovary, which latter is free from the calyx, and has 3 or 4 parietal placentas and as many clavate styles; fruit mostly succulent, stalked; seeds numerous, arillate; embryo straight, in thin fleshy perisperm.—Illustrative Genera: *Smeathmannia*, Soland.; *Passiflora*, Juss.; *Tetrapathæa*, DC.; *Dilkea*, Mast.

Affinities, &c.—This Order is generally associated with the Cucurbita-

ceæ, which it resembles in habit, and has a further affinity in the structure of the ovary, the most marked difference being the hermaphrodite flower, superior position of ovary, and the presence of perisperm in Passion-flowers. The coronet or wreath of filiform organs between the petals and the stamens, and the gynandrophore bearing the stamens and ovary, mark this Order out very clearly, and ordinarily its flowers are perfect; but the genus *Tetrapathæa* appears to connect it by a further link with Cucurbitaceæ, since the flowers are there polygamous or even diœcious. It is closely allied to Samydaceæ, in which, however, there is no corona. From Turnerads it differs in the gynandrophore, and marcescent not deciduous petals. The relations to Capparidaceæ, Bixaceæ, and Violaceæ are also well marked, and indeed its affinity to the latter Order is much closer than to the Cucurbits, with which it is usually associated; the floral formula is the same. The corona of Passion-flowers is an outgrowth from the flower-tube at the base of the petals.

Distribution.—Species numerous, mostly tropical or subtropical; the greater part are South-American and West-Indian; a few occur in North America, Africa, the East Indies, and Australia.

Qualities and Uses.—The pulpy fruits of many species of *Passiflora* (Granadillas), several *Tacsoniæ*, and of *Paropsia edulis* are eaten; but astringent properties exist in the leaves, while the roots of *Passiflora quadrangularis* and the flowers of *P. rubra* are narcotics. The beauty of the flowers and foliage renders this Order a very favourite one in cultivation.

CEÆ consist of a few unimportant herbs or low shrubs, natives of Chili and Peru, resembling Passifloraceæ in the structure of the flowers; but the coronet is merely a membranous ring, the styles arise from the backs of the carpels, and the seeds are not arillate. Included as a tribe of the preceding Order by Bentham and Hooker.

ACEÆ. Herbs or half shrubby plants, natives of the West Indies and South America, with 5-merous flowers, deciduous contorted petals with no corona, and a 1-celled superior ovary with 3 parietal placentas; seeds perispermic, with a strophiole or false aril. They appear to form a link, through Malesherbiaceæ, from the Passifloraceæ &c. to parietal Thalamifloral Orders, such as Cistaceæ. They have tonic and aromatic properties.—Genera: *Turnera*, Plum.; *Piriqueta*, Aubl.

SAMYDACEÆ form a tropical Order, chiefly of American plants, of somewhat doubtful place: apparently they stand nearest to Bixaceæ and the Thalamifloræ with parietal placentas; however, they are apetalous, and the stamens are perigynous, which relate them to a different set of Orders. One of their most striking peculiarities is the presence of both round and linear pellucid glands in the leaves. The bark and leaves of the plants are astringent, and those of species of *Casearia* are used in Brazil as febrifuge medicines.

CUCURBITACEÆ. THE CUCUMBER ORDER.

Coh. Passiflorales, *Benth. et Hook.*

Diagnosis.—Herbaceous plants, mostly succulent, prostrate or

climbing, with tendrils; leaves alternate; flowers diœcious or monœcious; the flower-tube adherent to the 1–3-celled ovary; corolla usually gamopetalous; and the 3–5 stamens commonly more or less united by their often sinuous anthers as well as by their filaments. Fruit a pepo, or, more rarely, a succulent berry. Placentas confluent in the axis; perisperm none.

Character.

Thalamus flat or concave, adherent to the ovary. *Calyx* adherent in the female flowers, 5-toothed, sometimes without a limb. *Corolla* of distinct valvate petals, or 4–5-parted, sometimes fringed; springing from the calyx, and with the lobes alternating with those of the calyx. ♂. *Stamens* 5, springing from the corolla and alternate with its segments, more rarely 3 or 2, sometimes free, monadelphous, or more frequently triadelphous, with 2 pairs and 1 odd one; *anthers* 2-celled, usually long and sinuous, or bent upon themselves laterally (fig. 383), sometimes straight,

Fig. 382.

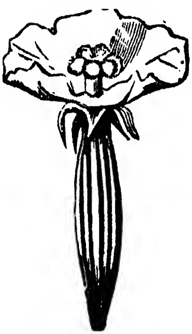


Fig. 383.

Fig. 384.

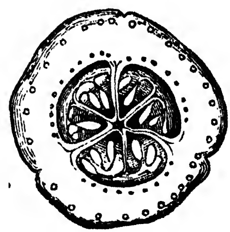


Fig. 382. Female flower of *Cucurbita*.
Fig. 383. Staminal column of male flower of Gourd.
Fig. 384. Section of the fruit of the Cucumber.

free, or combined. ♀. *Ovary* inferior (fig. 382), 3-celled; usually with 3 placentas placed parietally, but on the involute margins of the carpels so as to meet in the centre (fig. 384), sometimes with 2 placentas and 2 erect ovules, or 1-celled with a solitary pendulous ovule: *style* short; *stigmas* thickened, papillose, lobed or fringed. *Fruit* more or less succulent; a pepo with a firm rind, or a juicy berry with a thin skin; *seeds* mostly flattened, with a succulent or membranous coat over the leathery or horny testa, which presents a marginal ring or keel; *embryo* flat, without perisperm.

Illustrative Genera.

Series 1. Plagiospermeæ. *Ovules horizontal.*

Feuillæa, *L.*
Bryonia, *L.*
Citrullus, *Neck.*
Ecbalium, *L. C. Rich.*
Momordica, *L.*
Cucumis, *L.*
Cucurbita, *L.*

Series 2. Orthospermeæ. *Ovules erect or ascending.*

Trianosperma.
Elaterium.

Series 3. Cremospermeæ. *Ovules pendulous.*

Sicyos, *L.*
Sechium, *P. Br.*

Affinities, &c.—The Cucurbitaceæ, divided as above into 3 series, are still further divided by Hooker into 8 tribes according to the number of the stamens, the form of the anthers, the nature of the placentas, and the number of the ovules, &c. They form a very well-defined Order, but have affinities of a very diversified range. The habit and the placentation ally them closely with Passifloraceæ, from which they differ, however, in the position of the ovary, the unisexual flowers, the peculiar structure of the anthers, and the want of perisperm. Their nearest relations among the epigynous Orders, after Begoniaceæ, appear to be the Loasaceæ, through *Gronovia*, which agrees in its climbing habit, and comes near the *Sicyeæ*. In the structure of the ovary and seeds and the position of the stamens there is a certain approach to the polypetalous Onagraceæ, Myrtaceæ, &c., and, further, to the monopetalous Campanulaceæ. Again, the diclinous condition and the structure of the ovary connect them with Papayaceæ. This Order presents a number of points of interest as regards structure. The tendrils appear here to be partially metamorphosed leaves, while their base is constituted of an abortive branch; but they have been referred by various botanists to leaves, stipules, peduncles, branches, and even roots. Their position by the side of the leaf is very curious, and accords with Warming's suggestion that the tendril is an extra-axillary branch, arising as it does from a flat cellular outgrowth outside the leaf-axil. Warming also describes the following structures as emerging from the axil of the leaf in many Cucurbits:—1. A terminal ♂ or ♀ flower; 2. A leaf-bud; 3. An inflorescence homodromous with the principal axis, antidromous with the leaf-bud. In *Thladiantha dubia*, according to Dutailly, the tendril and the male flower replace one another morphologically, being never found together, but the one always in the place of the other. The andrœcium of these plants has been considered to consist of five stamens, with unilocular anthers, united into three parcels; but by others it is asserted that these plants have three stamens, two with two-celled anthers, and one with a one-celled anther. Traces of the abortive stamens may, however, be detected in the vascular bundles, so that the typical structure of the andrœcium is pentamerous. The construction of the ovary of the *Cucurbiteæ* is remarkable, the sides of the carpels being inflected to the centre, and then rolled in further upon themselves until the marginal placentas are brought back nearly to the circumference of the fruit; hence, although termed parietal placentas, they are rather an excessive case of the inflexion which ordinarily produces axile placentas. The form of the fruit is varied: the pepo assumes almost every modification of globular, oval, bottle-shaped, sausage-

like, or even snake-like form; some kinds are dehiscent: in *Ecbalium* it bursts by separating from its peduncle and expelling the seeds with violence through the orifice; in *Momordica* and others it bursts irregularly; in *Elaterium* it bursts by two or three valves at the summit; and in some species of *Luffa* an orifice is formed at the top by the separation of the scar of the calyx. In *Sechium* the pepo contains only one seed, which germinates within the fruit, and never separates from it, so that the fruit resembles a thick root-stock.

Distribution.—A considerable Order, the species of which are chiefly natives of hot climates, especially abounding in the East Indies, but some found almost anywhere; *Bryonia dioica* is the only British species.

Qualities and Uses.—The majority of the plants of this order are to be looked upon as suspicious, from the prevalence of a purgative property, sometimes very violent, sometimes slight, and apparently liable to affect particular constitutions more strongly than others. Some kinds may be reckoned as poisons, while others, especially when cultivated, although they retain laxative qualities, become innocuous. Among the decided purgatives, *Ecbalium agreste*, the dried juice of the fruit of which furnishes "Elaterium," is one of the most drastic agents known. Colocynth is the extract of the pulp of *Citrullus Colocynthis*; the fruits of several species of *Luffa* and *Lagenaria* are strongly purgative; the roots of the various species of *Bryonia* are actively cathartic; and the same quality resides in the seeds of *Feuillæa cordifolia*, &c. Some other plants of the Order share this quality, although the seeds are generally harmless.

On the other hand, the milder species furnish fruits highly esteemed either as fruits, for their delicate flavour in their fresh state, as in the Melon and the Cucumber, or as pot-herbs, from the succulent, bland, pulpy substance of the unripe or ripe fruit, as of the Gourds. *Cucumis Melo* is the common Melon; *Cucumis sativus* is the Cucumber; *Cucurbita Citrullus* is the Water-melon; *Cucurbita Pepo* is the White Gourd, *C. maxima* the Red Gourd or Pumpkin; the Vegetable-marrow is a variety of *C. Pepo*. The Snake-gourd, *Trichosanthes anguina*, is eaten in India, also many other species of Cucurbitaceous plants, which appear to become much milder under cultivation. The fruit of *Sechium edule* is also eaten in hot countries. The seeds are oily; some are harmless, as those of *Telfairia pedata* (Africa), which are said to be as large as chestnuts, and are eaten like almonds, and the oil expressed. The pulp surrounding them is very bitter.

BEGONIACEÆ (Elephant's Ears) are herbaceous plants or low succulent shrubs with an acid juice; leaves alternate, oblique at the base, with large scarious stipules; flowers monœcious; sepals coloured, those of the barren flowers in two pairs, decussating; those of the fertile flowers 5, imbricated, or 8; stamens indefinite, distinct or coherent in a column; anthers clustered; ovary inferior, 3-celled, with 3 dissepimental placentas meeting in the axis; stigmas 3, sessile, 2-lobed; fruit capsular; seeds aperispermic, with a thin reticulated testa.—Illustrative Genera: *Begonia*, L.; *Hillebrandia*, Oliv.

Affinities, &c.—The relations of this interesting and numerous Order have been variously conceived by different authors; but they appear to be

near Cucurbitaceæ, the so-called parietal placentas of the latter being rather an excessive form of the double axile placentas of such plants as *Diploclinium*, and the placentas of *Mezieria* are described as parietal. *Hillebrandia* has nearly regular flowers, and the ovary opens at the top as in *Reseda*. It confirms the relationship to Datiscads. *Begoniella* has a bell-shaped gamophyllous perianth and definite stamens.—They are natives chiefly of India, South America, and the West Indies, and are much cultivated for their beauty; the oblique or unequal-sided leaves are characteristic, whence they are sometimes called Elephant's Ears. Many *Begonias* are remarkable for the production of adventitious buds in great numbers from various parts of their surface. The roots appear to be bitter and astringent, sometimes purgative. *B. malabarica, tuberosa,* and some others are used as pot-herbs.

DATISCACEÆ are diclinous apetalous herbs or trees, with alternate, exstipulate, simple or compound leaves; barren flowers with a 3-4-merous perianth, and 3–7 stamens; fertile ones with an adherent 3-4-toothed perianth, a 1-celled ovary with 3–4 many-seeded parietal placentas, and a dry fruit opening at the summit.—They consist of a few species very widely scattered. *Datisca cannabina* is found in the south-east part of Europe, and has bitter and purgative properties. The Order appears so nearly related to Cucurbitaceæ, Begoniaceæ, and Loasaceæ, that it is undesirable to place it among the Monochlamydeæ. *D. cannabina* is remarkable as affording one of the examples of a tendency of the female flowers of diœcious plants to mature seeds without impregnation; this phenomenon has been observed frequently in *Cælobogyne* and *Mercurialis* among the Euphorbiaceæ and in *Cannabis*; but some error of observation is to be suspected in these cases. *Tetrameles* is a large tree, the rest are herbs.—Genera: *Datisca*, L.; *Tetrameles*, R. Br.; *Tricerastes*, Presl.

is a small Order of tropical trees or shrubs with inferior ovaries and parietal placentas, related on the one hand to Passifloraceæ, on the other to Loasaceæ and Cactaceæ. They are included in Samydaceæ by Bentham and Hooker; some of them have been introduced into cultivation on account of their foliage; the flowers are small.—Genera *n*, Jacq.; *Blackwellia*, Commers., &c.

LOASACEÆ comprise herbs, sometimes hispid with stinging hairs; leaves opposite or alternate, without stipules; calyx adherent, 4–5-parted; petals 5 or 10, in 2 circles, often cucullate; stamens numerous, free or in bundles, adherent to the petals, often intermixed with staminodes or abortive stamens; ovary adherent, 1-celled, with several parietal placentas or 1 central; ovules pendulous; seed with a loose testa; embryo in the axis of fleshy perisperm.—Illustrative Genera: *Mentzelia*, L.; *Bartonia*, Sims.; *Loasa*, Adans.; *Blumenbachia*, Schrad.; *Gronovia*, L.

Affinities, &c.—A small Order. The genus *Gronovia*, with a climbing habit, connects this Order with Cucurbitaceæ, especially those with a single seed; but in the latter Order the seeds are aperispermic. It is likewise closely related to Cactaceæ, differing importantly in habit only from some genera. With Begoniads it agrees in the character of the seeds. A further affinity exists to the epigynous Order Onagraceæ; and among

those with a free ovary, Malesherbiaceæ, Turneraceæ, and Passifloraceæ exhibit some points of agreement.—They are natives of the warmer parts of America; but one occurs in Arabia and tropical Africa. They are principally remarkable for their stinging hairs, which produce more violent irritation than our indigenous Nettles. *Mentzelia hispida* has a purgative root. *Loasa*, *Bartonia*, &c. are often cultivated on account of the beauty of their flowers; but some of them are rendered less valuable by their stinging-property.

CACTACEÆ (Indian Figs) are fleshy and thickened, mostly leafless plants, of peculiar aspect, globular or columnar and many-angled, or flattened and jointed, usually with prickles. Flowers solitary, sessile; the calyx and corolla sometimes 4-merous, but generally undistinguishable and imbricated in several spiral cycles adherent to the 1-celled ovary; stamens indefinite; placentas parietal; fruit succulent; seeds numerous, parietal or in the pulp, aperispermic.

Illustrative Genera.

Tribe 1. Echinocacteæ. *Flower-tube prolonged beyond the ovary. Stem tubercled or spiny, rarely leafy.*

Mammillaria, *Haw.*
Echinocactus, *Link et Ott.*
Cereus, *Haw.*

Tribe 2. Opuntieæ. *Flower-tube not prolonged beyond the ovary. Stem branched, jointed.*

Rhipsalis, *Gærtn.*
Opuntia, *Tournef.*
Pereskia, *Plum.*

Affinities, &c.—These plants are generally distinguishable at first sight by the remarkable forms of their succulent stems and the absence of true leaves; but this anomalous condition of the stem is not a decisive character, nor does it even carry with it indications of affinity, since we find it among Euphorbiaceæ, in *Stapelieæ* among the Asclepiadaceæ, in Vitaceæ, and elsewhere. The ordinary forms scarcely require description; but it must be noticed that the leaf-like structures of *Epiphyllum* &c. are flattened branches, and the leaves are represented solely by spines in the common kinds, each tuft of spines representing an abortive shoot with undeveloped internodes; *Pereskia*, however, bears true leaves, sessile or stalked. The stems have a woody axis of the normal Dicotyledonous structure: the chief mass of the stem of the phylloid kinds is made up of the greatly developed cortical parenchyma; but the globular and columnar kinds are very solid: the wood is remarkable for a peculiarly formed spiral thickening of its cells; and the parenchyma of old stems is densely loaded with crystals of calcium oxalate.

The relations, as founded on the structure of the flowers, are, perhaps, closest with Loasaceæ, and beyond them with the Cucurbitaceæ, with, however, many important points of difference from the last. There is a considerable resemblance in certain respects to Mesembryanthaceæ; for the placentas of that Order and those of the present are apparently but slight modifications of a similar fundamental structure. Some degree of affinity exists between Cactaceæ and Ribesiaceæ; but the dicarpellary structure there and the perispermic seeds are important distinctions, and indicate a closer relationship of the latter plants to Saxifragaceæ.

Distribution.—A large Order, the members of which are almost exclusively found in the hotter parts of America, especially in dry situations. *Opuntia vulgaris* is naturalized in South Europe and elsewhere. A species of *Rhipsalis* occurs in Africa as well as in Ceylon.

Qualities and Uses.—A subacid juice is commonly present in these plants, whence some of them are esteemed as remedies in fevers; the pulpy fruit of some is agreeable on account of this quality, in others it is insipid and mucilaginous. Cattle are said to bruise the trunks of some species with their hoofs in order to browse on the succulent parenchyma. *Opuntia vulgaris* is the Prickly Pear, the fruit of which is esteemed in the south of Europe and America. The fruit of *O. Tuna* yields a carmine pigment; that of *Pereskia aculeata* is called the Barbadoes Gooseberry. *O. coccinellifera*, the Nopal plant, is celebrated as forming the habitation and sustenance of *Coccus Cacti*, the Cochineal insect. *Cereus grandiflorus*, *C. nycticalus*, and some others are noted for opening their magnificent flowers at night: these and many other species of this and other genera of the Order, such as *Epiphyllum*, *Phyllocactus*, *Rhipsalis*, &c., are highly valued in cultivation for their showy flowers; and the globular, columnar, and angular stems are not less remarkable, on account of their strange appearance.

RIBESIACEÆ or GROSSULARIACEÆ (Currants) are low shrubs, sometimes prickly, with alternate palmately lobed leaves, a 5-lobed calyx inseparable from the 1-celled ovary and bearing 5 stamens alternating with as many small petals. Fruit a 1-celled, inferior berry with 2 parietal placentas. Seeds numerous, imbedded in pulp; embryo minute, in abundant horny perisperm.—These plants were formerly associated in the same Order with Cactaceæ; but their structure differs importantly, and approaches so nearly to that of Saxifragaceæ, that *Polyosma* is placed among the *Escallonieæ* by some authors, and in this Order by others: the succulent fruit and the horny perisperm are almost the only criteria, since the placentas are parietal in some *Escallonieæ*. By Bentham and Hooker this Order is included under Saxifragaceæ as a distinct Tribe.—The plants occur in cool or shady localities in the temperate regions of Europe, Asia, and America. The agreeable acid fruits form the most striking character of this Order. The Gooseberry (*R. Grossularia*), the Black Currant (*R. nigrum*), the Red and White Currant (*R. rubrum*) are the most valuable kinds. The Black Currant is remarkable for the aromatic glands, which give a stimulant property. All contain malic acid. Other fruits of the Order resemble these, but are commonly either tasteless or excessively acid. Several species are showy garden shrubs, as *R. aureum*, *R. coccineum*, &c., in which the calyx is brightly coloured.

HAMAMELIDACEÆ (Witch-Hazels) are shrubs or trees, with alternate simple leaves and deciduous stipules; flowers in heads or spikes, often polygamous or monœcious; calyx adherent; petals narrow, valvate, involute or circinate in the bud, or absent; stamens twice as many as the petals, half sterile and scale-like, or numerous; pistil of 2 carpels, forming a 2-celled ovary, with 2 styles; ovules solitary in the cells or numerous; fruit a 2-beaked woody capsule with 1 seed in each of the two cells, bursting at the top; seeds perispermic.

ILLUSTRATIVE GENERA.

Tribe 1. HAMAMELEÆ. *Dichlamydeous; ovary with* 1 *suspended ovule in each loculus.*
Hamamelis, *L.*
Trichocladus, *Pers.*

Tribe 2. FOTHERGILLEÆ. *Monochlamydeous; ovary as in* Tribe 1.
Fothergilla, *L. f.*
Parrotia, *C. A. Mey.*

Tribe 3. ALTINGIEÆ. *Calyx often rudimentary; ovules several in each loculus of the ovary.*
Liquidambar, *L.*
Bucklandia, *R. Br.*
Rhodoleia, *Champ.*

Affinities, &c.—Lindley makes *Liquidambar* the type of a distinct Order, Altingiaceæ, associated with the Amentiferous Orders; but the relations between the genera above noted appear opposed to this. The flowers may be regarded as indicating an aberrant form, standing near Cornaceæ, from which they differ in their perigynous stamens, their multiple style, alternate exstipulate leaves, &c. They are also connected by Bruniaceæ with the Umbelliferæ. They approach closely to the Saxifrages, but have wood-cells marked with glandular dots and a large (not small) embryo, besides other points. The species are not numerous, but are widely diffused. The petals of *Hamamelis* are circinate in æstivation.—Various species of *Liquidambar* yield the pungent resin called Storax. *L. styraciflua* (North America) is an ornamental tree, the handsome 5-fid leaves of which turn red in autumn; its resin contains much benzoic acid. Most of the "liquid Storax" of commerce comes from the East, probably from *L. orientale* in the Levant, and *L. Altingia* in the Malay Islands. The bark of these trees is also acrid and bitter.

Æ is an Order of Heath-like shrubs, mostly found at the Cape of Good Hope, of unknown properties; in structure apparently connecting the Hamamelidaceæ with the Umbelliferæ, having an epigynous disk, and the heads of flowers sometimes surrounded by involucral bracts; but the petals are valvate. They have some degree of affinity to Myrtaceæ also, thus bringing these into relation with the Caprifoliaceæ and allied Orders.—Genera: *Brunia,* L.; *Staavia,* Thunb.

UMBELLIFERÆ OR APIACEÆ.

Coh. Umbellales, *Benth. et Hook.*

Diagnosis.—Herbs, generally with fistular stems, alternate exstipulate leaves sheathing at the base, and generally deeply divided; the regular hermaphrodite flowers in umbels; the tube of the calyx completely adherent to the ovary; the 5 petals and 5 stamens springing from the disk crowning the ovary and surrounding the base of the 2 styles (fig. 385); the fruit consisting of 2 separating, seed-like, dry carpels.

Character.

Thalamus concave, forming with the base of the calyx a tube

(flower-tube, calyx-tube) adherent to the ovary. *Calyx* limb 5-toothed, ring-like, or undistinguishable. *Corolla*: *petals* 5, distinct, springing from the outside of the fleshy disk, mostly inflexed at the point, sometimes bifid, often unequal in size. *Stamens* 5, alternate with the petals and emerging with them, incurved in the bud. *Ovary* inferior, 2-celled, composed of 2 coherent carpels, surmounted by a double fleshy disk or *stylopod*, from which project 2 divergent *styles*; *stigmas* simple; *ovules* 1 in each cell, pendulous. *Fruit* consisting of 2 seed-like halves (*mericarps*) separating at the *commissure*, remaining attached above to a forked carpophore (fig. 388), which was previously enclosed between them; each mericarp an indehiscent 1-seeded body, with the pericarp developed into longitudinal ridges (*juga*), 5 primary and sometimes 4 secondary, with intervening channels (*valleculæ*), in which often exist lines of oil-bearing tissue called *vittæ*; *embryo* in the base of abundant horny perisperm.

Fig. 385.

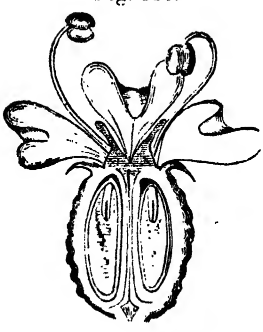


Fig. 386.

Fig. 387.

Fig. 388.

Fig. 385. Vertical section of the flower of *Fœniculum*.
Fig. 386. Cross section of the fruit of *Daucus*.
Fig. 387. Fruit of *Anthriscus*.
Fig. 388. Ripe fruit (mericarps) of *Conium* separating from the carpophore.

ILLUSTRATIVE GENERA.

Series 1. HETEROSCIADIÆ. *Umbels generally simple; vittæ none.*

Hydrocotyle, *Tournef.*
Mulinum, *Pers.*
Sanicula, *Tournef.*
Astrantia, *Tournef.*
Eryngium, *Tournef.*

Series 2. HAPLOZYGIÆ. *Umbels compound; primary ridges of fruit alone conspicuous; vittæ rarely absent.*

Echinophora, *L.*
Conium, *L.*
Cicuta, *L.*
Anthriscus, *L.*

Œnanthe, *Lam.*
Æthusa, *L.*
Angelica, *Hoffm.*
Ferula, *L.*
Heracleum, *L.*

Series 3. Diplozygiæ. *Umbels compound; fruit with both primary and secondary ridges well marked.*

Coriandrum, *L.*
Daucus, *L.*
Thapsia, *L.*

Affinities, &c.—The floral conformation may be thus expressed: | S 5 P 5 A 5 $\widehat{G\,2}$. The arrangement of the genera above given is that of Bentham and Hooker, who greatly reduce the number of genera cited by other authors. By De Candolle the Umbellifers were grouped under three Suborders:—1. *Orthospermeæ*; perisperm flat on the inner face: 2. *Campylospermeæ*; perisperm involute, with a vertical groove on the inner face: 3. *Cœlospermeæ*; perisperm inflexed above and below. The plants of this very extensive and important Order are in general readily recognizable by their inflorescence and fistular stems; but these characters are not always present, even in the indigenous forms; and it is instructive in this respect to examine the genera *Sanicula* and *Hydrocotyle*, where the umbels are little developed, and *Eryngium*, where the flowers are sessile and the involucral bracts so much developed as to give the umbels the appearance of the capitula of Composites. These deviations from the ordinary habit are still more striking in some of the exotic genera; for *Horsfieldia*, a Javan form, has capitulate heads arranged in panicles; and *Bolax*, an Antarctic genus, grows in a tufted manner, with imbricated leaves and nearly sessile umbels, so as to assume the outward appearance of some of the alpine species of *Androsace*. In some of the genera the leaves are entire, or the stalk of the leaf expanded into a blade-like form (*Bupleurum*, *Eryngium*). The essential character of the order lies in the fruit, by which they are known from all other plants. The form of the fruit, the structure and arrangement of the ridges and vittæ upon the pericarp, together with the form of the perisperm of the seed, and the characters presented by the inflorescence, furnish the characters by which the Order is subdivided; the latter character, although formerly regarded as primary, is now found to be too inconstant for that purpose.

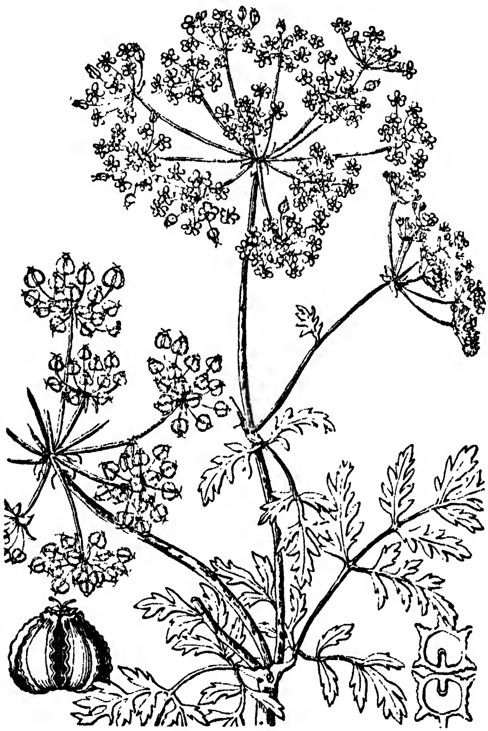
The relations of the Umbelliferæ are closest with the other epigynous Calycifloræ with definite stamens, especially Araliaceæ (from which their fruit differs), the Rubiaceæ (which have sympetalous corollas and opposite leaves and interpetiolar stipules), and the Cornaceæ (where the leaves are partly opposite, the flowers tetramerous, and the fruit succulent). In habit, as well as in dicarpellary structure, some of the Umbelliferæ approach the Saxifragaceæ. The resemblances to Geraniaceæ seem rather superficial: the carpophore is of very distinct character.

Distribution.—Abundant in the northern and central parts of Europe, Asia, and America; common upon the mountains of warmer regions, and again met with in the Southern hemisphere, but chiefly as dwarf and aberrant forms.

Qualities and Uses.—Several distinct classes of active secretions occur in the plants of this Order, which in some are extremely powerful, and in others slightly developed. The most important consist of acro-narcotic poisonous substances in solution in the watery juices; the second are gum-resinous substances, and becoming milky when exposed to the air;

and the third are aromatic oils especially developed in the vittæ of the pericarps. Many have the watery juices innocuous and the gum-resinous secretion mild, so that they become esculent vegetables, which are rendered still more bland when they acquire a more succulent condition under cultivation. The absence of light has a remarkable effect in preventing the development of the aromatic principles, as is seen in blanched garden Celery and other cases.

Fig. 389.



The Hemlock (*Conium maculatum*).

A number of the poisonous kinds are indigenous, one of which, *Conium maculatum*, Hemlock (fig. 389), is in use in medicine as an anodyne. *Æthusa Cynapium*, Fool's Parsley, is a common weed; *Circuta virosa*, Water Hemlock, is not uncommon; *C. maculata* of North America is equally poisonous; *Œnanthe crocata*, Hemlock Dropwort, *Œ. Phellandrium*, and other species are noted as poisonous, although they lose the property under certain circumstances. *Anthriscus sylvestris* and *vulgaris* are said to be

poisonous. Accidents occur from the resemblance of the foliage of these plants to Parsley, and of the roots of *Œnanthe* and others to Parsneps. *Hydrocotyle asiatica* is used in cases of leprosy.

The plants furnishing the antispasmodic gum-resins are mostly natives of warmer regions than the poisonous kinds, and some doubts exist as to the exact species which yield certain of these substances. Asafœtida is believed to be derived from *Narthex Asafœtida* and *Scorodosma fœtida*. *Ferula orientalis* (Morocco) yields an analogous resin. Sagapenum is supposed to be obtained from another species of *Ferula*. Gum Ammoniacum is from a Persian plant called *Dorema Ammoniacum* and *Dorema gummiferum*. Opoponax is the resin of *Pastinaca Opoponax* (*Opoponax Chironum*). The source of Gum Galbanum is supposed to be *Ferula galbaniflua* and *rubricaulis*.

The flavour of Celery (*Apium graveolens*), Parsley (*Petroselinum sativum*), Fennel (*Fœniculum vulgare*), Angelica (*Archangelica officinalis*), Eryngo (*Eryngium maritimum* and *campestre*), of the Carrot (*Daucus Carota*), and the Parsnep (*Pastinaca sativa*) depend on a volatile oil contained in the rind and leaves; but more concentrated in the vittæ of the pericarp, which renders the fruits of these plants powerfully aromatic, whence they are often used for flavouring in cooking; the fruits of the Caraway (*Carum Carui*), Dill (*Anethum graveolens*), Coriander (*Coriandrum sativum*), Anise (*Pimpinella Anisum*), Cummin (*Cuminum Cyminum*), *Ammi copticum*, and others are especially valued for these essential oils.

The roots of the Carrot and Parsnep, the root of *Arrachaca esculenta* (New Granada), the stem and petioles of Celery, when rendered very succulent by cultivation, retain only a moderate quantity of the aromatic oils, and are then chiefly valuable for their saccharine and mucilaginous qualities. Samphire, made into pickles, is *Crithmum maritimum*, a species growing on maritime rocks. The roots of Chervil (*Anthriscus Cerefolium*) were formerly eaten. The tubers of the species of *Bunium* are edible. Alexanders (*Smyrnium Olusatrum*) was formerly cultivated like Celery. Sumbul root is the produce of *Euryangium Sumbul*, and is employed as a tonic and stimulant.

ARALIACEÆ (THE IVY ORDER) consists of herbs, shrubs, or trees, with characters resembling those of Umbelliferæ, but usually with more than 2 styles, and the fruit 3- or several-celled, succulent or dry, with one perispermic seed in each cell.—Illustrative Genera: *Panax*, L.; *Aralia*, L.; *Hedera*, L.; *Adoxa*, L.; *Gunnera*, L.; *Helwingia*, Willd.

Affinities, &c.—The Araliaceæ stand very close to the Umbelliferæ, but may be distinguished by the ovary having more than 2 carpels. Most of the plants have also a valvate æstivation of the corolla, while it is imbricated in the Umbelliferæ: there are some exceptions to the rule in the latter Order; and *Adoxa* is an exception here. Seemann separates as a distinct Order, under the name Hederaceæ, all Umbelliferous plants with valvate petals and a fruit composed of two or more carpels. The true Araliads, according to this author, have imbricated petals. They are not so exclusively herbaceous as the Umbelliferæ, some being trees, and some climbing shrubs, which latter bring the Order into relation with the Vitaceæ. They are nearly allied to Caprifoliaceæ, which have a sympetalous

corolla. *Adoxa,* referred to Caprifoils by Bentham and Hooker, is remarkable for its stamens, which have a bipartite filament, each half bearing a separate anther-lobe; it also presents flowers with 4- and 5-merous corollas in the same inflorescence. *Gunnera,* an aberrant form, included under Halorageæ by Bentham and Hooker, is in some cases diœcious, has a dimerous perianth of two whorls or none at all, and 2 stamens, and a 1-celled, 1-seeded ovary; *G. scabra* is remarkable for its enormous leaves, as much as 8 feet in diameter, on stalks like those of *Rheum.* *Helwingia* is unisexual, and is made a type of a distinct Order by Decaisne and others. Its flowers are collected on the midribs of the leaves or bracts, from the adherence of the peduncle, somewhat as in *Tilia.* Seemann includes in his proposed group of Hederaceæ, on account of their valvate, not imbricate, petals, *Crithmum, Horsfieldia,* some species of *Hydrocotyle,* and some other plants usually placed in Umbelliferæ.

Distribution.—A considerable Order, distributed throughout all climates and in all parts of the world.

Qualities and Uses.—Aromatic and stimulant. The root of *Panax Ginseng* is highly valued by the Chinese as a stimulant; *P. quinquefolium* is exported to China from the United States as American Ginseng. *Aralia nudicaulis* (United States) is called Wild Sarsaparilla; *A. racemosa* yields an aromatic gum-resin. The astringent roots of *Gunnera scabra* are used for tanning, and the fleshy leaf-stalks are eaten. The berries of Ivy (*Hedera Helix*) are emetic and purgative. The wood of some of the East-Indian species is resinous and aromatic. The substance called Rice-paper, prepared by the Chinese, consists of thin slices of the pith of *Tetrapanax papyriferum.*

Fig. 390.

Ripe fruit of *Cornus.*

CORNACEÆ (THE DOGWOOD ORDER) consists of shrubs or trees (rarely herbaceous), almost always with opposite and exstipulate simple leaves; flowers 4–5-merous, sometimes diclinous; the tube of the calyx adherent to the 1–2-celled ovary, its limb minute; the petals (valvate in the bud), with as many stamens, inserted on the margin of an epigynous disk in the perfect flowers; style 1; a single anatropous ovule suspended from the top of each cell; the fruit drupaceous, 1–2-seeded (fig. 390); embryo nearly the length of the perisperm, with large and foliaceous cotyledons.—Illustrative Genera: *Cornus,* Tournef.; *Aucuba,* Thunb.

Affinities, &c.—The chief distinctions from the Araliaceæ lie in the inflorescence, the tetramerous structure of the flower, the usually opposite leaves, the 2-carpellary ovary, and the simple style; from Umbelliferæ the first two characters divide them, together with the single style, and in most cases the habit; Caprifoliaceæ are distinguishable by the sympetalous corolla. Haloragaceæ differ in habit and distinct styles, but are connected with this group through *Gunnera.*

Distribution.—A small Order, the members of which are natives of the temperate parts of America, Europe, and Asia.

Qualities and Uses.—The bark of various species of *Cornus* is esteemed as a tonic and febrifuge; *C. florida* &c. are used in North America in

place of Cinchona; *Cornus sanguinea*, Dogwood, is a common hedge shrub. *C. mascula*, the Cornelian Cherry, bears fruit, which is now little esteemed. *Aucuba japonica*, the variegated or "Cuba" Laurel of our shrubberies, is the female form of a diœcious Japanese plant, propagated in thousands by layers, but till lately never producing seeds. Since the introduction of the male plant, however, the scarlet olive-shaped berries are produced in profusion; and numerous varieties have been raised from seed.

Division II. **Gamopetalæ** or **Corollifloræ.**

Dicotyledonous Flowering plants having both calyx and corolla, the latter sym- or gamopetalous and springing directly from the receptacle; the stamens mostly adherent to the corolla (epipetalous), rarely free and arising with the corolla from the receptacle. Gynæcium usually syncarpous.

Exceptions, &c.—The prevailing floral formula is $\widehat{S\,5} \mid \widehat{P\,5}\ A\,5\ \widehat{G\,2}$, but similar anomalies to those noted under the other Subclasses occur in some Orders which, on the whole, are Corollifloral. Thus, among Ericaceæ, the Suborder *Vaccinieæ* is properly Calycifloral, and the same thing occurs in Styracaceæ and elsewhere; among the Ericaceæ and Epacridaceæ we sometimes have the Thalamifloral condition, the petals being distinct and the stamens hypogynous. In Primulaceæ, Oleaceæ, and Plantaginaceæ apetalous and polypetalous species occur. In Lobeliaceæ, Primulaceæ, Myrsinaceæ, Sapotaceæ, Styracaceæ, Jasminaceæ, and Plumbaginaceæ dialypetalous corollas occur, but with epipetalous stamens; and also, in some cases, apetalous flowers with hypogynous stamens, which, strictly speaking, would be Monochlamydeous. These (and many other cases might be noted) indicate the continual occurrence of "cross relations" between the groups of Orders, which render it very difficult to arrange the Orders satisfactorily, and show that any linear series is quite artificial. The Gamopetalous Orders may be grouped according to the position of the ovary, superior or inferior, the number of carpels, the regularity or irregularity of the corolla and stamens, &c.; but in any case allowance must be made for exceptions.

Series 1. Inferæ or Epigynæ.

Ovary usually inferior. Stamens isomerous with the lobes of the corolla, rarely fewer.

CAPRIFOLIACEÆ. The Honeysuckle Order.

Coh. Rubiales, *Benth. et Hook.*

Diagnosis.—Shrubs or rarely herbs, with opposite leaves and as, a rule, no stipules; the tube of the flower adherent to the ovary; the stamens as many as (or one less than) the lobes of the tubular or rotate epigynous corolla, and attached to its tube; ovary 1–6-celled, often with 1 ovule in

one cell and several in the others; style 1; stigmas 3 or 5; fruit indehiscent, dry or succulent, 1- or more-celled; seeds solitary or numerous, pendulous; embryo in fleshy perisperm.—Illustrative Genera: *Diervilla*, Tournef.; *Lonicera*, Desf.; *Viburnum*, L.; *Sambucus*, Tournef.

Affinities, &c.—This Order is usually subdivided into two Suborders:—1. Lonicereæ, with a tubular, regular or irregular corolla, a filiform style, and seeds with a dorsal raphe; and 2. Sambuceæ, with regular rotate corollas, 3 sessile stigmas, and seeds with ventral raphe. It connects the sympetalous Rubiaceæ, Loganiaceæ, and their allies with the dialypetalous Cornaceæ and Umbelliferæ. Through the *Escalloniecæ* it is also connected with the Saxifragaceæ.

Distribution.—A considerable Family, distributed chiefly in the northern parts of Asia, Europe, and America.

Qualities and Uses.—Some of the plants possess powerful purgative and emetic properties, as in the case of the leaves of the Elder (*Sambucus nigra*), of the Gueldres Rose (*Viburnum Opulus*), the Common Honeysuckle (*Lonicera Periclymenum*), and *Triosteum perfoliatum* (North America). The fruits seem comparatively destitute of this property, that of our Elder and others being made into wine; the berries of *Viburnum* are eaten in North America; and those of *Symphoricarpus*, the Snow-berry of our shrubberies, appear to be harmless. The fragrance and beauty of the flowers are marked characters of the Order. Besides Honeysuckles, species of *Lonicera* and *Caprifolium*, the Elder, the species of *Viburnum* (*V. Opulus*, grown in gardens for its balls of white *neuter* flowers, *V. Lantana*, the mealy Gueldres Rose, *V. Tinus*, the Laurustinus shrub), *Symphoricarpus*, &c. are found in every shrubbery. By Bentham and Hooker the curious little genus *Adoxa* is included in this Order.

RUBIACEÆ. The Madder Order.

Coh. Rubiales, *Benth. et Hook.*

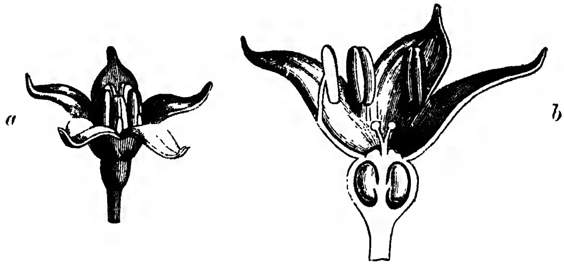
Diagnosis.—Herbs, shrubs, or trees, with opposite entire leaves connected by interposed stipules, or in real or apparent whorls with stipules resembling the leaves; the calyx adherent to the 2–4-celled ovary; the stamens as many as the lobes (3–5) of the regular epigynous corolla, and springing from its tube; ovules anatropal; embryo perispermic.

Character.

Thalamus concave, together with the calyx tube adherent to the ovary. *Calyx* limb entire or 4–6-toothed, sometimes obsolete. *Corolla* sympetalous, regular, with a long tube, or rotate, its segments equal in number to the teeth of the calyx. *Stamens* usually equal in number to the lobes of the corolla, and attached in one line upon it, alternately with them. *Ovary* inferior, usually 2-celled, with an epigynous disk; *style* single, sometimes slightly divided; *stigmas* united or divided; *ovules* solitary, 2 or

many in each cell. *Fruit* splitting into two dry cocci, or indehiscent, and then dry and succulent, 2-celled, 2- or many-seeded; *seeds*, if definite, erect or ascending, or numerous on axile placentas; embryo in horny perisperm.

Fig. 391.



Rubia: *a*, flower, nat. size, showing *obsolete* calyx, gamopetalous corolla, &c.; *b*, section of the flower.

ILLUSTRATIVE GENERA.

By Bentham and Hooker the immense Order Rubiaceæ is divided into twenty-five tribes, which latter are grouped into series and subseries as follows:—

SERIES I. *Ovules indefinite.*

Subseries 1. *Fruit dry, capsular, or indehiscent.*

Tribes—Naucleæ, Cinchoneæ, Henriquezieæ, Condamineæ, Rondeletieæ, Hedyotideæ.

Subseries 2. *Fruit fleshy or coriaceous, indehiscent.*

Tribes—Mussændeæ, Hamelieæ, Catesbæeæ, Gardenieæ.

SERIES II. *Ovules geminate in each cell.*

Tribes—Cruckshanksieæ, Retiniphylleæ.

SERIES III. *Ovules solitary in each cell.*

Subseries 1. *Radicle superior.*

Tribes—Guettardeæ, Knoxieæ, Chiococceæ, Alberteæ, Vanguerieæ.

Subseries 2. *Radicle inferior.*

Tribes—Ixoreæ, Morindeæ, Coussareæ, Psychotrieæ, Pœdericæ, Anthospermeæ, Spermacoceæ, Galieæ.

The distinctions between the Tribes are founded on the æstivation of the corolla, the winged or not winged seeds, the nature of the inflorescence, and of the fruit, &c.

Affinities, &c.—The Rubiaceæ are often divided into two Orders, Cinchonaceæ and Galiaceæ, or Stellatæ, the latter including all the genera with large foliaceous stipules, or, as they are termed, whorled leaves: the distinction does not appear to be sufficient. The presence of interpetiolar stipules, either small or imitating leaves, is the principal character separating this Order from Caprifoliaceæ, where, however, Lindley observes that they sometimes occur as monstrous growths. This Order also runs very close

to Loganiaceæ, being chiefly distinguished by its inferior ovary; the Loganiaceæ thus connect it with Gentianaceæ and the allied Corollifloral Orders. The fruits of the *Galiæ*, and of some of the *Coffeæ*, nearly relate them to the Umbelliferæ; from which, however, they may be at once known by the gamopetalous corolla. *Opercularia*, an aberrant genus with a 1-celled, 1-seeded ovary, connects the Order with Dipsaceæ; and the inflorescence of some kinds, as *Cephalanthus*, *Richardsonia*, &c., approaches the condition of the capitula of that Order and of Compositæ; while in *Argyrophyllum* the stamens are syngenesious.

Distribution.—This is one of the largest Orders. The *Stellatæ* or *Galieæ* belong to the cool parts of the Northern hemisphere and the mountains of the Southern. The *Coffeæ* and *Cinchoneæ* are chiefly natives of warm climates, most of them tropical.

Qualities and Uses.—The Rubiaceæ form a very extensive group, and include plants with a considerable diversity of properties. Some are emetic and purgative; others febrifuge and tonic; others stimulant and restorative; some are astringent; a few have edible fruits; some yield valuable dye-stuffs; and fragrant or showy flowers abound in the Order. Among the powerfully emetic plants are the Ipecacuan, the officinal substance being the creeping rhizome of *Cephaelis Ipecacuanha*. *Psychotria emetica* furnishes a spurious kind called *black* or streaked Ipecacuan. *Richardsonia scabra* and *emetica* yield *white* false Ipecacuan. *Chiococca densifolia* (Cahinca root) and *C. anguifuga* have similar properties, which are shared by the genera *Spermacoce*, *Manettia*, &c. Most of the above plants belong to Brazil. The two species of *Chiococca* above named are regarded as specifics against snake-bites; their emetic and purgative action is described as excessively powerful. Some species of *Cephaelis* and *Psychotria* are still more active, and are used as poisons for rats and mice in Brazil. Coffee consists of the seeds of *Coffea arabica*, two of which are produced in a succulent berry. It is believed to be a native of Abyssinia, perhaps also of Arabia, but is now widely diffused in cultivation in the East and West Indies and Brazil. Liberian Coffee is a native of Western Africa. The fruits of *Galium* are said to bear some resemblance to Coffee when roasted.

Cinchona, Peruvian or Jesuits' bark, is derived from several trees natives of the slopes of the Andes, at an elevation of about 7000–8000 feet, and many of which are now cultivated in India. The researches of Weddell, Howard, and others have determined the source of most of the kinds. *Cinchona Calisaya* gives Yellow or Calisaya bark; *C. succirubra*, Red bark; *C. nitida* and *micrantha*, Grey or Huanaco bark; *C. Condaminea* (var. *vera*), Crown or Loxa bark. The bark of various species of *Exostemma* is known as false Cinchona. Species of *Guettarda*, *Pinckneya*, *Rondeletia*, *Coutarea*, &c. have similar properties. The extract of the leaves of *Uncaria Gambir* is a powerful astringent, known as Gambeer among the Malays, and supposed to furnish part of the Catechu of commerce.

Among the fruits may be mentioned those of *Genipa* (Brazil and Madagascar), *Sarcocephalus esculentus*, the Sierra Leone Peach, &c. The berries of some *Coprosmæ* are eaten in Australia, and are called Native Currants.

Of the dyes, Madder, the roots of *Rubia tinctorum* (Europe), *R. cordifolia*, Munjeeth (Bengal), *R. Relboun* (China), and *R. angustissima* are the most important *Oldenlandia umbellata*, used instead of Madder in

the East Indies; species of *Morinda, Psychotria, Genipa, Condaminea*, &c. are of less importance. *Guettarda speciosa* furnishes what is called by cabinet-makers "Zebra-wood," from the West Indies.

Among the genera noticed in the list above are found many of our favourite stove-plants, noted, like *Gardenia*, for fragrance, or, like *Ixora*, for their splendid blossoms and handsome foliage. Many species of *Galium* are common weeds with us, readily known by their star-like whorls of leaves and stipules.

VALERIANACEÆ (THE VALERIAN ORDER) consists of herbs with opposite simple or compound leaves and no stipules; the tube of the flower adherent to the ovary, which latter has 1 fertile and 2 abortive or empty cells; the limb of the calyx is obsolete or forms a pappus; corolla epigynous, tubular, 3–6-lobed (lobes imbricate), sometimes spurred at the base; stamens 1–5, distinct, fewer than the teeth of the corolla, attached to its tube, alternate with the lobes; seeds solitary, in the fertile cell of the dry, indehiscent, sometimes pappose fruit, pendulous, aperispermic; radicle superior.—Illustrative Genera: *Fedia*, Mœnch; *Centranthus*, DC.; *Valeriana*, Neck.

Affinities, &c.—This Order approaches Dipsaceæ in general structure, sometimes having involucrate inflorescence; hence it is also related to Compositæ, Campanulaceæ, &c.; but the peculiar structure of the ovary is a very marked character, and the seed of Dipsaceæ is perispermic. The development and unrolling of the pappus of *Centranthus* and others, during the ripening of the fruit, is very singular: the corolla is surrounded by a thickened ring, which subsequently enlarges and expands into a crown of feathery processes.

Distribution.—An extensive Order, the members of which are distributed throughout the temperate parts of Europe, Asia, and America.

Qualities and Uses.—Many of the plants have strong aromatic properties, whence they are used as antispasmodic and tonic remedies. *Valeriana officinalis, Phu, celtica*, and *Saliunca* are all used; *V. sitchensis*, from Russian America, is said to be the most powerful. *Nardostachys Jatamansi* (India) is supposed to be the ancient Spikenard. *Fedia* or *Valerianella olitoria* is cultivated for salad, under the name of Lamb's Lettuce. *Centranthus ruber*, a showy plant, with abundant cymes of small rose-coloured flowers, is found in most gardens, and is naturalized in Kent.

DIPSACEÆ (THE SCABIOUS ORDER) is composed of herbs with opposite or whorled leaves, no stipules; the flowers in dense heads surrounded by an involucre as in Compositæ; the separate florets surrounded by special membranous involucels; calyx adherent, limb scaly or pappose; corolla epigynous, tubular, mostly irregular, 4–5-lobed, inserted on the calyx, imbricated in æstivation; stamens 4, sometimes half-barren, attached to the tube of the corolla; anthers distinct; ovary 1-celled, with 1 pendulous ovule, simple style and stigma; fruit indehiscent; seed perispermic; radicle superior.—Illustrative Genera: *Dipsacus*, Tournef.; *Scabiosa*, Röm. et Schult.

Affinities, &c.—Nearly related to Valerianaceæ on one hand, and to Compositæ on the other; distinguished from both by its involucels and peri-

spermic seed; from Compositæ especially by the distinct anthers and pendulous seed.

Distribution.—The species number about 120, and are found most abundantly in Southern Europe and North and South Africa. None are American.

Qualities and Uses.—Some are said to be astringent. The Teazel (*Dipsacus fullonum*), a large Thistle-like plant, is of great importance, its dried capitula being used to comb up the nap on cloth, the hooked bracts not tearing the stuff like metal instruments. Many species of *Scabiosa* (Scabious) are cultivated for their beauty; two small-flowered species are natives of Britain.

CALYCERACEÆ are a small Order of South-American plants, intermediate between Dipsaceæ and Compositæ, having the pendulous perispermic seed of the former, and anthers coherent below and free above, so as to approach the syngenesious character of the latter Order. Properties unknown.—Genera: *Boopis*, Juss.; *Calycera*, Cav.

COMPOSITÆ.

Coh. Compositales, *Benth. et Hook.*

Diagnosis.—Herbs or shrubs; the flowers in dense heads (capitula) upon a common receptacle surrounded by an involucre; stamens 5 (rarely 4), springing from the corolla, filaments free; anthers coherent into a tube surrounding the style (syngenesious); ovary inferior, 1-celled, with 1 erect ovule; seed aperispermic.

Character.

Capitula at the extremity of an enlarged peduncle surrounded by an involucre of bracts, and bearing perfect and imperfect *florets* closely packed, all similar, or of two kinds, those of the centre or disk and those of the circumference or *ray*; florets often accompanied by membranous scale-like bracts (*paleæ*). *Calyx*

Fig. 392.

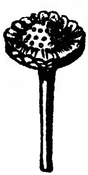


Fig. 393.

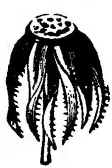
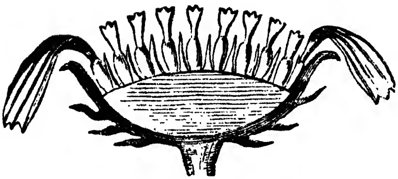


Fig. 394.

Fig. 392. Receptacle of the Daisy with the florets removed.
Fig. 393. Receptacle of Dandelion with the florets removed; bracts of the involucre reflexed.
Fig. 394. Linear stigmas of Compositæ.

Fig. 396.

Fig. 395.



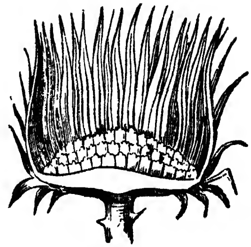


Fig. 398.

Fig. 397.

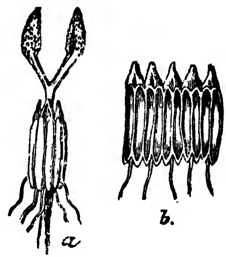


Fig. 395. Section of a capitulum of a Composite plant with paleæ at the base of the central tubular and of the marginal ligulate florets.
Fig. 396. Section of an empty capitulum of a Composite plant with a paleaceous receptacle.
Fig. 397. Tubular floret. The pappus is scaly.
Fig. 398. Ligulate floret. Pappus scaly.
Fig. 399. Syngenesious anthers and styles of Compositæ: *a*, in the natural position; *b*, the tube of anthers opened.

adherent; limb obsolete, entire, or replaced by a circle of scales, bristles, or feathered or simple hairs (*pappus*), which is often persistent. *Corolla* sympetalous, epigynous (fig. 397) and funnel-shaped, or ligulate (fig. 398), or bilabiate. *Stamens* 5, alternate with the teeth of the corolla; *filaments* distinct; *anthers* cohering into a tube round the style (fig. 399). *Ovary* inferior, 1-celled, with 1 erect ovule; *style* simple below, bifid at the apex, with a distinct *stigmatic* surface on each branch (figs. 394, 399). *Fruit* a "cypsela" (figs. 400–402), indehiscent, with 1 erect aperispermic *seed*, often crowned by the pappus.

This extensive Order is divided into three Suborders.

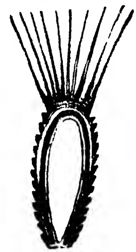
1. Tubulifloræ. Florets all tubular and perfect, or only those of the centre (*disk*) perfect, while those of the circumference are

tubular or ligulate, and female or neuter. —2. LABIATIFLORÆ. Florets with bilabiate corollas, perfect or unisexual.—3. LIGULI- Florets all ligulate and perfect; juice milky.

g. 400.

Fig. 401.

Fig. 402.



Figs. 400–402. Fruits of Compositæ surmounted by the pappus. In fig. 400 the calyx-tube is elongated above the fruit in the shape of a "beak." (Fig. 402, vertical section, showing the erect seed.)

ILLUSTRATIVE GENERA.

By Bentham the Composites are divided into thirteen tribes:—I. Vernonieæ. II. Eupatorieæ. III. Asteroideæ. IV. Inuloideæ. V. Helianthoideæ. VI. Helenioideæ. VII. Anthemideæ. VIII. Senecionideæ. IX. Calenduleæ. X. Arctotideæ. XI. Cynaroideæ. XII. Mutisiaceæ. XIII. Cichoraceæ.

These tribes are founded upon the uni- or bisexual character of the florets in each head, the form of the florets (tubular, ligulate, &c.), the form of the anthers and of the projections from their base and apex respectively, the form of the style and stigmas, the nature of the pappus, &c. The following genera may be taken as representatives of the above tribes:—

I. *Vernonia.* II. *Eupatorium.* III. *Aster.* IV. *Inula.* V. *Helianthus.* VI. *Tagetes.* VII. *Anthemis.* VIII. *Senecio.* IX. *Calendula.* X. *Arctotis.* XI. *Carduus.* XII. *Mutisia.* XIII. *Taraxacum.*

Affinities, &c.—This Order, which is the most numerous, and, by some authors, regarded as the most perfect in the Vegetable Kingdom, is likewise very natural, its distinguishing features being very evident in almost every genus. From its nearest allies, Dipsaceæ and Calyceraceæ, it may be distinguished by the condition of the anthers and the ovule. The syngenesious condition, and, in some measure, the general structure of the florets, ligulate and tubular, indicate a near relation also to Lobeliaceæ and Campanulaceæ, wherein, however, the flowers are not only large and scattered, but the ovaries have more than one cell, with many seeds in each cell.

The floral formula is | S5? $\widehat{P5}$ $\widehat{A5}$ $\widehat{G2}$, but the nature of the calyx and pappus is undetermined. Two different views are held as to the nature of the pappus. Some (as Lund, Treub, Buchenau) look on it as truly a modified calyx: Warming considers it in the light of trichomes or hairs having no definite position or order. Hofmeister regards the pappus of Composites, Valerianaceæ, and Dipsaceæ as a whorl of leafy

formations, and considers it probable that each hair is the representative of a leaf. In the development, however, the corolla precedes the calyx, which is often represented by a mere rim, so as to render it doubtful whether a true calyx-limb really exists.

The subdivisions of this Order are differently given by different authors. The most recent revision is that of Bentham above cited. The Orders of the Linnean Class Syngenesia correspond to Compositæ. Tubulifloræ, as above given, include the Corymbiferæ of some authors, in which the style of the perfect flowers is not swollen below the stigma, and the Cynareæ, where the outer florets are often neuter and the style is swollen below the stigmas. The tribes of the Compositæ established by De Candolle depend on the condition of the style and its stigmatic lobes. The characters of the genera are chiefly derived from the conditions of the involucre, the cypselous fruit, and the pappus.

Distribution.—The species are more numerous than those of any other family, more than ten thousand being known, and are universally distributed, forming one eighth of the Phanerogamia of Central Europe; the *Tubulifloræ* are most abundant in hot climates, the *Cichoraceæ* in cold. The *Labiatifloræ* belong almost entirely to extratropical South America. In the northern hemisphere the Compositæ are all herbaceous; in South America and some other parts of the southern hemisphere they are sometimes shrubby. Fossil Composites are first found in the Upper Miocene beds (Saporta).

Qualities and Uses.—The plants of this Order are not generally characterized by any very powerful properties: bitterness is the prevailing quality, accompanied by aromatic secretions in the *Corymbiferæ*, and by a special lactescent juice in the *Cichoraceæ*, which often contains a more or less active narcotic principle.

Among *Corymbiferæ* may be noticed a number of genera possessing considerable importance. The *Artemisiæ*, or Wormwoods, are numerous; *A. Absinthium* and *pontica* are Wormwoods proper, and with some other species are used not only as anthelmintics, as their name indicates, but for preparing the bitter liqueurs called *Absinthe* or Vermuth; *A. Dracunculus* is the Tarragon, the leaves of which are used in salads and pickles; *A. Abrotanum* is Garden Southernwood, used also for its bitter flavour. Most of the other species have similar properties; the flower-heads of *A. Contra, Sieberi, pauciflora, Vahliana,* &c. are known on the Continent, under the name of Semen Cinæ or Semen Contra, as powerful vermifuges. *A. chinensis* furnishes Moxa. *Anthemis nobilis,* the Camomile, *Matricaria Chamomilla,* and *Pyrethrum Parthenium* are valued for aromatic bitter and tonic properties; the species of *Achillea* are astringent, or in some cases pungent, which is still more the case with *Anacyclus Pyrethrum,* called Pellitory of Spain, and *A. officinarum,* the dried roots of which provoke an active flow of saliva, and are used as a remedy for toothache: in a fresh state these roots are acrid; and this is still more the case with *Maruta fœtida*. *Arnica montana,* a plant of the mountains of Central Europe, is narcotic-acrid and poisonous, except in small doses; its tincture has a powerful influence in exciting the circulation beneath the skin without producing vesication. *Doronicum Pardalianches* is said to have similar properties, as also some species of *Inula*; *Inula Helenium,* however, is merely aromatic and tonic; it is known under the name of Elecampane.

Some species of *Eupatorium*, including our native *E. cannabinum*, are emetic and purgative; *E. Ayapana* (Brazil) has a reputation as a local and internal application for snake-bites. Matico is said to be obtained from *E. glutinosum*, though most of it is the produce of *Artanthe elongata*, a Piperaceous plant; its leaves are used as a styptic.

The seeds of some of the *Corymbiferæ* contain much fixed oil. The seeds of the Sunflower (*Helianthus annuus*) are well known on this account; and *Madia sativa* (Chili) has become an object of cultivation in France and Germany for the sake of the oil expressed from its seeds, its "oil-cake" being also valuable for cattle. The esculent tubers called Jerusalem or *Girasole* Artichokes are furnished by *Helianthus tuberosus*; the analogous tubers of the Dahlia (*Dahlia variabilis*) are not available in this way on account of a strong and unpleasant flavour which exists in them. *Tussilago Farfara*, or Coltsfoot, which is mucilaginous and bitter, was formerly in repute for affections of the chest.

The *Cynareæ*, or thistle-like Compositæ, are equally varied in the concentration of their qualities. The root of *Carlina acaulis* is said to be a violent purgative, and that of *C. gummifera* is known as an anthelmintic. The Burdock (*Arctium Lappa*), the Marigold (*Calendula officinalis*), *Centaurea Calcitrapa*, and other allied plants were formerly esteemed as febrifuges, diuretics, and alteratives, but have gone out of use. The Costus, celebrated by the ancients for its virtues, is supposed to be the root of *Aucklandia costus* (Cashmere). *Carthamus tinctorius*, Safflower, is used in dyeing and in the manufacture of true rouge; the flowers of *Calendula officinalis* are used to adulterate Saffron. *Serratula tinctoria* is also used in dyeing yellow and green. The Globe Artichoke is the fleshy receptacle, with its bracts, of *Cynara Scolymus*; Cardoons are the blanched stems and petioles of *Cynara Cardunculus*.

The *Labiatifloræ* are sometimes aromatic, bitter, or mucilaginous. The leaves of *Printzia aromatica* are used as a Tea at the Cape of Good Hope; those of *Anandria discoidea* are used by the Chinese as the Coltsfoot is in Europe.

The *Cichoraceæ* include several plants of note: the different kinds of Lettuce, *Lactuca virosa*, *Scariola*, *sativa* (the Garden Lettuce), contain a milky juice which has narcotic properties; when evaporated to dryness it forms a kind of gum, called by druggists Lactucarium, which is occasionally used as a sedative. The Garden Lettuce loses much of its bitterness, and, at the same time, of its narcotic properties, in cultivation. The Dandelion, *Leontodon Taraxacum* (or *Taraxacum Dens Leonis*), has also a milky juice, which is valued for its medicinal properties as a diuretic and alterative, with some sedative qualities; its roots, and still more those of Chicory or Succory (*Cichorium Intybus*), are used, roasted, to adulterate coffee. Besides the Lettuce we have other esculent vegetables in this Suborder: *Cichorium Endivium* furnishes the Salad Endive (blanched by exclusion of light); Scorzonera is the root of *Scorzonera hispanica*, other species of which are used in like manner in different countries; Salsafy is the root of *Tragopogon parvifolius*, or Goat's-beard.

The Compositæ include a vast number of cultivated plants. The Dahlia (*D. variabilis*), the Chrysanthemum (*Pyrethrum sinense*, *indicum*), the Cinerarias (*Senecio cruenta*, *Tussilaginis*, *Heritieri*), the China Aster (*Callistemma hortense*) are florist's flowers remarkable for the number and beauty of their varieties. The Everlasting flowers, or *Immortelles*, are

mostly species of *Gnaphalium*, together with *Helichrysum*, *Aphelexis*, &c. Our native Thistles are species of *Carduus*, *Onopordum*, &c.

LOBELIACEÆ are herbs or shrubs with a milky juice, alternate leaves, and scattered flowers; corolla irregular, epigynous, sympetalous, split down to the base on one side; the 5 stamens free from the corolla and united into a tube, often by their filaments, and always by their anthers; ovary inferior, 1-3-celled; style 1; stigma 2-lipped, surrounded by a fringe of hairs; seeds numerous, perispermic.—Illustrative Genera: *Lobelia*, L.; *Siphocampylus*, Pohl.

Affinities, &c.—The relations of this Order to Compositæ are close, as is seen when we compare the flowers with ligulate florets of the *Cichoraceæ*: the structure of the ovary, however, as well as of the inflorescence, divides them. With Campanulaceæ, under which order they are included as a tribe by Bentham and Hooker, they are connected through the tubular florets of Compositæ, which resemble the flowers of Campanulaceæ, except in the structure of the ovary, which brings the Campanulaceæ still nearer to Lobeliaceæ. The fringe round the stigma is analogous to the hairs of the style of Campanulaceæ, and perhaps also to the indusium of Goodeniaceæ. Some Lobeliaceæ have their petals distinct, and *Monopsis* has the flower nearly regular.

Distribution.—A rather large Order, the members of which are chiefly distributed throughout tropical and subtropical regions.

Qualities and Uses.—The milky juice is acro-narcotic; the species of *Lobelia* are more or less poisonous, producing effects analogous to those of Tobacco. *Lobelia inflata* is used in small doses for spasmodic asthma; it acts sometimes as an emetic, but produces great depression of the pulse, perspiration, and, in large doses, death. Most of the species are acrid when fresh; *L. urens* produces vesication of the skin. *Tupa Feuillei* (Chili) yields a violent poison. *Isotoma longiflora* is vesicatory, and, taken internally, produces death from violent and uncontrollable purging. The milky juices contain Caoutchouc. Many species of *Lobelia* and *Siphocampylus* are cultivated for their showy flowers.

GOODENIACEÆ consitute an Order of plants allied to the Lobeliaceæ, the Stylidiaceæ, and the Campanulaceæ; but especially distinguished by the remarkable structure of the upper part of the style, which is expanded into a kind of cup or purse, concealing within it the stigmatic surface, and closing over the pollen after fertilization.—Most of the Goodeniaceæ are Australian and Polynesian; a *Scævola* occurs in North-western India and in Africa; another genus, *Selliera*, is South-American. Their properties are unimportant. *Leschenaultia formosa*, *cærulea*, and other species are cultivated on account of the beauty of their flowers.

BRUNONIACEÆ, consisting of two species of *Brunonia*, Australian plants, agree with Goodeniaceæ in the structure of the style, but are sometimes separated from them on account of the superior position of the ovary. Their capitulous inflorescence approaches that of Compositæ. They have no known properties.

STYLIDIACEÆ constitute a small Order of plants related to the Goodeniaceæ and the Campanulaceæ, but are distinguished by and remarkable

for the gynandrous structure of the flowers, the filaments being adherent to the style into a column surmounted by the anthers which overlie the stigma. This column exhibits the irritability met with here and there in Flowering Plants: in *Stylidium* it hangs over on one side of the flower; but when touched it rises up and springs over to the opposite side, at the same time opening its anthers and scattering the pollen.—The *Stylidia* are chiefly from Australia; a few others are scattered in the East Indies; the *Forsteræ* belong to New Zealand and the Straits of Magellan. They have no known properties.

CAMPANULACEÆ. Bell-flowers.

Coh. Campanules, *Benth. et Hook.*

Diagnosis.—Herbs with a milky juice, alternate leaves, and mostly scattered flowers: calyx adherent to the ovary: corolla regular, epigynous, bell-shaped, valvate in æstivation: stamens 5, free from the corolla, mostly distinct or coherent just below the base of the distinct anthers: ovary 2–5-celled; style 1, hairy; stigma simple or lobed; capsule many-seeded, dehiscent by lateral orifices or valves at the top: seeds with fleshy perisperm.—Illustrative Genera: *Jasione*, L.; *Campanula*, L.

Affinities, &c.—The Campanulaceæ are divided by Bentham and Hooker into three tribes: —1. *Lobeliceæ*, here treated as a distinct Order, and having irregular flowers and syngenesious anthers; 2. *Cyphieæ*, with irregular flowers and free anthers; and 3. *Campanuleæ*, with regular flowers and usually free anthers. They have many points of agreement with the Compositæ, the flowers resembling the tubular florets of that Order in the corolla, inferior position of the ovary, and number and position of the stamens; but the anthers are distinct or only united at the base, and the ovary is more than 1-celled and contains many seeds; in *Jasione* and *Phyteuma* the flowers are in capitula, almost like those of Compositæ. They are only separated from Lobeliaceæ by the regularity of their flowers, the globular (not elliptical) pollen-grains, and the peculiar hairs of the style; which points of structure likewise separate them from Goodeniaceæ and Stylidiaceæ. On the other hand they approach *Vaccinieæ*, from which they differ in the number of the stamens and their porous dehiscence, the style, and the habit. In *Cyclocodon* the tube of the corolla is adherent to the ovary (superior), while the calyx is inferior!

Distribution.—A large Order, the members of which belong mostly to the temperate parts of the Northern hemisphere.

Qualities and Uses.—The milky juice has properties analogous to that of the Compositæ, and is sometimes rather acrid; but the young roots and shoots, especially when cultivated, are often edible; Rampions are the roots of *Campanula Rapunculus*; *Specularia Speculum* and other species have been used in salads. The *Campanulas*, commonly known as Canterbury Bells, Hair-bells, &c., are numerous in cultivation; and other genera have also handsome flowers.

Series 2. SUPERÆ.

Ovary usually superior (inferior in *Vaccinieæ*).

ERICACEÆ. THE HEATH ORDER.

Coh. Ericales, *Benth. et Hook.*

Diagnosis.—Shrubs or sometimes herbs, with regular or nearly regular flowers; corolla gamo- or polypetalous, hypogynous or epigynous (*Vaccinieæ*); stamens as many or twice as many as the petals of the 4–5-lobed or 4–5-petalous corolla, free from the corolla, hypogynous or epigynous; anthers 2-celled, commonly with appendages, and opening by terminal chinks or pores (figs. 404, 405); style 1; ovary 3–10-celled; seeds small, anatropous; embryo small or minute, in fleshy perisperm.

Fig. 404. Fig. 405. Fig. 403.

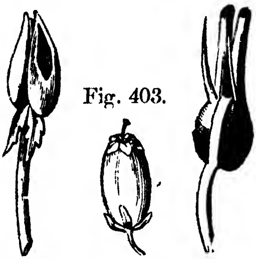


Fig. 403. Flower of *Erica*.
Fig. 404. Stamen of *Erica*.
Fig. 405. Stamen of *Vaccinium*.

The Ericaceæ are divisible into four very distinct Suborders, which are sometimes ranked as Orders:—

1. VACCINIEÆ. Shrubby, or more or less woody herbs, with an adherent calyx, sympetalous epigynous corolla, epigynous stamens, 2-parted anthers opening by pores, containing 4-nate pollen-grains; the inferior ovary becoming a berry surmounted by the teeth of the calyx.—2. ERICINEÆ. Shrubs or small trees, with a free calyx; a sympetalous or polypetalous corolla springing with the stamens from the receptacle; anthers opening by pores.—3. PYROLEÆ. Woody herbs with evergreen foliage; calyx free; corolla of 5 distinct hypogynous petals; stamens hypogynous; anthers porous; seeds with a loose cellular testa and minute nucleus.—4. MONOTROPEÆ. Fleshy herbs with scale-like leaves, destitute of green colour; calyx free; corolla sym- or dialypetalous; stamens hypogynous; pollen simple.

ILLUSTRATIVE GENERA.

Suborder I. VACCINIEÆ. Oxycoccus, *Tournef.*; Vaccinium, *L.*

Suborder II. ERICINEÆ.

Tribe 1. ARBUTEÆ. *Corolla deciduous. Fruit succulent. Evergreen shrubs.* Arbutus, *Tourn.*

Tribe 2. ANDROMEDEÆ. *Corolla deciduous. Capsule loculicidal. Shrubs with persistent leaves. Buds usually scaly.* Andromeda, *L.*

Tribe 3. ERICEÆ. *Corolla persistent, often 4-merous. Fruit not capsular. Buds not scaly.* Erica, *L.*

Tribe 4. Rhodoreæ. *Corolla deciduous. Fruit capsular, septicidal. Buds scaly, cone-like.* Azalea, *L.*; Rhododendron, *L.*; Ledum, *L.*

Suborder III. Pyroleæ. Chimaphila, *Pursh*; Pyrola, *Tournef.*

Suborder IV. Monotropeæ. Monotropa, *Nutt.*; Schweinitzia, *Ell.*; Pterospora, *Nutt.*

Affinities, &c.—The general floral formula is $\widehat{S\,5}\ \widehat{P\,5}\ A\,5+5\ \widehat{G\,5}$, but in *Vaccinieæ* it is $|\ \widehat{S\,5}\ \widehat{P\,5}\ A\,5+5\ \widehat{G\,5}$. The Suborders are connected by the general plan of structure; but the details are subject to wide variation, not only including sympetalous and dialypetalous conditions, but even hypogynous and epigynous. By many authors these subdivisions are ranked as distinct Orders. The *Vaccinieæ*, with their inferior ovary, stand, if separated, among the epigynous Orders, near Campanulaceæ or Cinchonaceæ; consequently they form a connecting link between the Calycifloral and Corollifloral, indicating the artificiality of this division; they even appear related to the perigynous Calycifloral by *Escallonieæ* in Saxifragaceæ. The *Ericineæ* differ from the *Vaccinieæ* principally in the superior ovary and hypogynous corolla; and the stamens are here nearly if not quite hypogynous, which, with the many-celled ovary, divides them from Gentianaceæ and allied Orders. The *Ericineæ* are nearly allied to the Epacridaceæ; but the latter have 1-celled anthers. The *Pyroleæ* have the sepals and petals more or less distinct, are more herbaceous in habit than the foregoing, and their seeds are remarkably different; *P. aphylla*, a plant devoid of green colour, and with leaf-scales in place of leaves, connects this Suborder with *Monotropeæ*, which, however, differ in the dehiscence of the anthers, and in having the minute embryo at the apex instead of at the base of the fleshy perisperm. Some doubt exists whether the last Suborder are really parasitical plants: they grow among the fibrils of the roots of trees, and have all the appearance of parasites, but may live on decaying vegetable matter. In habit they resemble Orobanchaceæ; but this is not a sign of affinity.

Distribution.—A large Order, the members of which are generally diffused in temperate climates over heathy and boggy tracts, in subalpine and alpine localities, all over the world—the *Rhododendra* especially in India, the *Befariæ* in South America, and the Heaths at the Cape.

Qualities and Uses.—The general character is astringency. The fruits of various *Vaccinieæ* and *Ericeæ* are edible—as those of *Oxycoccus palustris* and *O. macrocarpa* (the European and North-American Cranberries), *Vaccinium Myrtillus* (the Bilberry), *V. Vitis-Idæa* (the Red Whortleberry), and *V. uliginosum* (the Black Whortleberry), *Gaultheria procumbens*, *G. hispida* (Tasmania), &c. But others are dangerous or even narcotic poisons; and this extends to the foliage of such kinds, especially species of *Rhododendron*, *Azalea*, *Andromeda*, *Kalmia*, &c. Uva-Ursi leaves (*Arctostaphylos Uva-Ursi*) are mixed with Tobacco by the North-American Indians, and are esteemed as astringents; those of some *Pyroleæ*, as *Chimaphila umbellata*, American Wintergreen, are used as diuretics. Oil of Wintergreen, known as an antispasmodic agent, and used in perfumery, is obtained from the fruit of *Gaultheria procumbens*. A vast number of species of *Erica*, *Rhododendron*, *Azalea*, &c., with numerous varieties and

hybrids, are objects of cultivation on account of the peculiarity and beauty of their flowers. They especially constitute what are called "American Plants" by gardeners, the American *Rhododendra, Azaleæ,* and *Kalmiæ,* &c. being those which first strongly occupied the attention of florists. Some of the East-Indian *Rhododendrons* are epiphytes.

EPACRIDACEÆ are closely related to Ericaceæ, but are distinguished by the one-celled anthers opening by a chink; the filaments are also commonly adherent to the corolla. The Order is commonly divided into two Tribes:—1. Stypheliеæ, with one ovule in each cell of the ovary, and fleshy fruits; and 2. Epacreæ, with numerous ovules in each cell of the ovary, and capsular fruit. They are peculiar to Australia, the Indian archipelago, and the South-Sea Islands, occurring in great abundance, in the same way as the *Ericeæ* do at the Cape of Good Hope. They do not appear to possess any active properties: many of them bear succulent berries; and some of them are eaten, as those of *Lissanthe sapida, Astroloma humifusum,* the Tasmanian Cranberry, &c. Many of the Epacridaceæ are in cultivation on account of the beauty of their flowers.

PLANTAGINACEÆ are chiefly herbs with undeveloped stems and tufts of leaves spreading more or less on the ground; flowers spiked, regular, 4-merous, the 4 stamens attached to the tube of the hypogynous dry and membranous sympetalous corolla, alternating with its lobes; the filaments long and slender, and the anthers versatile; ovary simple, but spuriously 2- or 4-celled by temporary adherence of the angles of the free central placenta to the walls; ovules 1, 2, or numerous, peltate; style and stigma simple, the latter rarely cleft; capsule membranous, dehiscence circumscissile; seeds 1, 2, or many, perispermic; the testa mucilaginous.—Illustrative Genera: *Littorella,* L.; *Plantago,* L.

Affinities, &c.—This Order appears to find its nearest relatives in Plumbaginaceæ and Primulaceæ, from which, however, the position of the stamens, alternating with the lobes of the corolla, distinguishes it, in addition to other characters noticed under those Orders. The affinity to Amaranthaceæ and Chenopodiaceæ does not appear well made out. Baron von Mueller suggests an affinity with Loganiads. In *Littorella* there is a tendency to abortion in one or other set of essential organs.

Distribution.—A not very extensive group, the species of which are generally diffused, but most abundant in temperate climates.

Qualities and Uses.—The foliage is slightly bitter and astringent. The seeds of many species of *Plantago,* such as *P. Psyllium, arenaria, Cynops,* &c., were much used formerly on the Continent, under the name of Semen Psyllii and S. Pulicariæ, or Flea-seed, for making mucilaginous drinks like those prepared from linseed. The seeds called Ispaghulæ are the product of *Plantago decumbens*; the spikes of the fruit of *P. major* are much gathered in the green state under the name of Plantain, for feeding caged birds. *P. major, minor,* and *lanceolata,* called Plantains or Road-weeds, are among the commonest of our weeds on road-sides, in meadows, and all undisturbed ground where the soil is not very light. They are sometimes grown for sheep food.

PLUMBAGINACEÆ (THE THRIFT ORDER) consists of maritime or mountain herbs or under-shrubs, often with undeveloped stems and clustered leaves; flowers regular, 5-merous, with a plaited calyx; the 5 stamens superposed to the separate petals or the lobes of the sympetalous corolla; the free ovary 1-celled, with a solitary ovule hanging from a long funiculus which arises from the base of the cell; styles 5, rarely 3 or 4; fruit either utricular or dehiscent by valves above; seed with a simple testa and little perisperm.—Illustrative Genera: *Statice*, L.; *Plumbago*, Tournef.

Affinities, &c.—This Order is strongly characterized by the peculiar attachment of its ovule: this, with the numerous styles, separates it from the Primulaceæ, which it approaches in the position of the stamens and some other points; the same characters, with the position of the stamens, distinguish it from Plantaginaceæ; and these marks, with the plaited calyx, isolate it from all the other Corollifloral Orders, among which it claims a place in spite of the occasionally dialypetalous or even apetalous condition.

Distribution.—A rather large group; some kinds are found all over the world on the sea-shore; others are more local in similar habitats, in salt-marshes and in saline steppes, while others, again, belong to alpine regions.

Qualities and Uses.—The properties are either bitter and astringent, or acrid and caustic. The roots of *Statice caroliniana* are powerfully astringent; those of *Plumbago europæa, zeylanica, scandens*, and others are very active blistering-agents when fresh; that of *P. europæa* is used dried as a remedy for toothache. *P. toxicaria* is said to furnish a poison in Mozambique. The Garden Thrift (*Armeria vulgaris*), commonly used for edging, like Box, is said to be an active diuretic: the dried flowers are used for this purpose. Small doses of the root of *Plumbago europæa* are said to act as an emetic. The flowers of many of the Plumbaginaceæ, especially species of *Statice*, are very handsome, and many are cultivated on this account.

PRIMULACEÆ. THE PRIMROSE ORDER.

Coh. Primulales, *Benth. et Hook.*

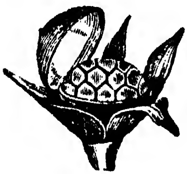
Diagnosis.—Herbs with opposite or alternate simple leaves and regular, perfect flowers; the stamens as many as the lobes of the sympetalous (rarely dialypetalous) hypogynous corolla, and superposed to them in the tube; ovary 1-celled, with a free central placenta bearing numerous perispermic seeds, a simple style, and a capitate stigma.

Character.

Thalamus flat or slightly convex. *Calyx* 5- or rarely 4-cleft, free or half-adherent, regular, persistent. *Corolla* hypogynous, sympetalous, and the limb regularly 5-, or rarely 4-cleft; or more

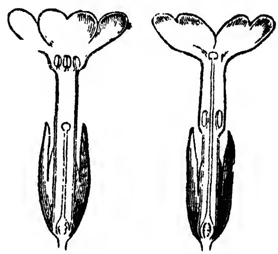
rarely composed of separate petals, or absent. *Stamens* equal in number to the petals or lobes of the corolla and adherent to them; or in apetalous flowers hypogynous and alternating with the teeth of the calyx. *Ovary* 1-celled, with a free central placenta bearing many ovules; *style* single; *stigma* capitate. ***Fruit***: a capsule opening by valves, more rarely circumscissile (fig. 406), many-seeded; *seeds* peltate; the embryo in fleshy perisperm.

Fig. 406.



Capsule of *Anagallis* opening by circumscissile dehiscence.

Fig. 407.



Polyanthus: *a*, stamens exserted, style included; *b*, style exserted, stamens included. (Seen in section.)

ILLUSTRATIVE GENERA.

Tribe 1. PRIMULEÆ. *Ovary free; capsule valvular; hilum ventral.* Primula, *L.*

Tribe 2. ANAGALLIDEÆ. *Ovary free; capsule opening transversely; hilum ventral.* Anagallis, *Tournefort.*

Tribe 3. HOTTONIEÆ. *Ovary free; capsule valvular; hilum basilar. Aquatics.* Hottonia.

Tribe 4. SAMOLEÆ. *Ovary semi-inferior; capsule valvular; hilum basilar.* Samolus, *L.*

Affinities, &c.—This is an Order which strongly attracts the attention of Structural Botanists on account of the peculiarities and anomalies which it presents. It is one of those in which the free central placenta is most distinctly seen, forming an exception to the very general rule of the placentas arising from the margins of the carpels. It seems to be truly axial in most cases, but in some monstrosities an appearance is presented as though the placentiferous lines were detached from the edges and surfaces of the carpels and reunited into a central column. In the next place the position of its stamens opposite or superposed to the petals is an exception to the rule of alternation of the organs of successive floral whorls, explained by supposing an intermediate whorl of stamens to be suppressed (in favour of which may be cited the condition of *Samolus*, *Lysimachia ciliata*, and others, where five teeth, which may be abortive stamens, alternate with the lobes of the corolla), or by the hypothesis

of *chorisis*, according to which the stamens are outgrowths from the petals. On the other hand, it has been urged that the petals are outgrowths from the stamens and are not autonomous organs. In *Samolus* we have the calyx partially adherent to the ovary. In some foreign genera the petals are either nearly or quite distinct. In *Trientalis europæa* the lobes of the calyx, corolla, and the number of stamens vary from 5 to 9. In *Glaux* the corolla is absent, and the calyx coloured. The ordinary floral formula would be $\widehat{S5} \left| \begin{array}{l} \widehat{P5}\ \widehat{G5} \\ A5 \end{array} \right.$, that of *Samolus* $|\ \widehat{S5}\ \widehat{P5}\ A\,5 + 5\ \widehat{G5}$.

The relations to Plumbaginaceæ are very close, both in the structure and the habit of many kinds, as between *Androsace* and some *Primulæ* and *Armeria*, &c.; but the solitary ovule of that family is a distinctive character. The Primulaceæ are still nearer to the exotic Order Myrsinaceæ as regards the structure of the flowers; but those are trees or shrubs with berry-like fruits, and have minor characters of distinction noticed under that Order. They approach Solanaceæ in habit, but not in structure.

Distribution.—A considerable family, the species of which are chiefly found in temperate and cold parts of the Northern hemisphere, in alpine regions or on the sea-shore when in lower latitudes.

Qualities and Uses.—The Cowslip (*Primula veris*) and other species appear to possess sedative properties. The *Soldanellæ* are slightly purgative. The Cyclamens have a fleshy tuber which is more or less acrid; and *Cyclamen europæum* is said to be a drastic purgative. The most remarkable quality is perhaps the beauty of the flowers, for which a great number are cultivated, especially species of *Primula*, which includes the Cowslip, the Primrose proper (*P. vulgaris*), the Polyanthus, a garden variety of this, the Oxlip (*P. elatior*), the Auricula (*P. Auricula*, from the Alps), the Chinese Primrose (*P. prænitens*), the Japan Primrose (*P. japonica*), &c. Many dwarf species of *Primula* and *Androsace* are "alpine plants," as is also *Soldanella*. *Glaux* and *Samolus* belong to salt-marshes; *Hottonia* to freshwater brooks, having feathery submerged leaves; the *Lysimachiæ* mostly grow in wet places. Many of the genera are represented in our native flora; while *Androsace*, *Dodecatheon*, and *Soldanella*, which are mostly alpine plants, are commonly cultivated.

Myrsinaceæ are so closely related to Primulaceæ in the structure of the flowers that no absolute character of distinction can be drawn therefrom, since the imbedding of the ovules in the placenta, general here, occurs in several Primulaceous genera, for example in *Anagallis*. But the Myrsinaceæ are of shrubby or tree-like habit, and their fruit is fleshy. They belong chiefly to the islands of the Southern hemisphere; and some of them are cultivated in this country as evergreen shrubs requiring protection in winter. The seeds of some species of *Theophrasta* and *Myrsine* are nutritious; and the berries of some plants of the Order are edible, although others are said to be cathartic.

Ægicераceæ include a genus of plants growing on sea-shores in the tropics, and rooting from the seed-vessels like Rhizophoraceæ, and considered to form a distinct Order by some writers. *Ægiceras* differs from

Myrsinaceæ chiefly in having aperispermic seeds, a follicular fruit, and transverse dehiscence of the anthers.

SAPOTACEÆ are trees or shrubs, mostly with a milky juice; leaves alternate, simple and entire (leathery and often rusty-downy beneath); flowers small, regular and perfect, usually in axillary clusters; calyx free and persistent; the fertile stamens commonly as many as the lobes of the short hypogynous corolla, and opposite to them, attached to the tube along with one or more rows of appendages and scales or sterile stamens; anthers extrorse; ovary 4–12-celled, with a single anatropous ovule in each cell; seeds large, usually perispermic.—Illustrative Genera: *Chrysophyllum*, L.; *Isonandra*, Wight; *Bassia*, Kön.

Affinities, &c.—Allied to Myrsinaceæ, but distinguished by the placentation, anatropal ovules, and other important characters,—also to the Ebenaceæ, which they resemble in habit; but they have a milky juice, and wood generally of a soft character; other differences also exist in the perfect flowers, such as erect ovules, simple styles, &c.

Distribution.—A considerable group. Chiefly tropical: Asia, Africa, and America.

Qualities and Uses.—The plants of this Order are valuable for succulent fruits, febrifuge bark, oleaginous secretions, and peculiar gum-resins in the milky juices. Of the fruits, the Sapodilla Plum (*Achras Sapota*), the Marmalade (*A. mammosa*), the Star-apple (*Chrysophyllum Cainito*), and the Surinam Medlar (*Mimusops Elengi*) are the most noted. The bark of various species of *Achras* has been used as a substitute for Cinchona. The fruits of *Bassia butyracea* and *B. longifolia* yield a butter-like oil largely used in India; another species in Africa is said to yield the Shea or Galam butter mentioned by travellers. *Isonandra Gutta* is the tree from which Gutta Percha is obtained, by evaporating the milky juice. The seeds of *Argania Sideroxylon* contain a valuable oil.

EBENACEÆ are trees or shrubs with alternate entire leaves, without milky juice; flowers regular, polygamous, with the calyx free from the 3–12-celled ovary; the stamens twice or four times as many as the lobes of the corolla, often in pairs before them; anthers introrse; fruit a several-celled berry; ovules 1 or 2, suspended from the summit of each cell; seeds large, perispermic; radicle superior.—Illustrative Genera: *Royena*, L.; *Diospyros*, L.

Affinities, &c.—The Ebenaceæ are distinguished from the Sapotaceæ by several important characters noted under that Order; on the other hand, they approach the Aquifoliaceæ in many points, but are separated by their strongly coherent floral envelopes, usually numerous stamens, and twin ovules, &c. To the Oleaceæ they are allied by the placentation and other points; but the alternate leaves, more numerous stamens, and commonly diclinous flowers afford very marked distinctions. The Styracaceæ are also very near to this Order, but frequently have an adherent calyx, petals less coherent, and a simple style with a capitate stigma.

Distribution.—A considerable group, the members of which are distributed mostly in tropical India, but a few are scattered elsewhere.

Qualities and Uses.—The principal property which has been noted in these plants is astringency; but they are better known and far more important on account of their hard and dark-coloured wood, the heart-wood of many species of *Diospyros* constituting Ebony: *D. Ebenus* yields it in Mauritius; *D. Melanoxylon* on the Coromandel coast; *D. Ebenaster* is the bastard Ebony of Ceylon; and *D. hirsuta* has a variegated wood called Calamander. Other species are also used. *D. virginiana*, a North-American species, bears the fruit called Persimmon or Date-plum, which is astringent when ripe, but is eaten after it has been affected by frost. *Diospyros Lotos* (Europe) and *D. Kaki* (China) have also edible fruit.

AQUIFOLIACEÆ OR ILICACEÆ (THE HOLLY ORDER) comprise trees or shrubs, with small axillary 4–6-merous flowers, sometimes diclinous by abortion; a minute corolla free from the 4–6-celled ovary and the 4–6-seeded berry; the stamens as many as the divisions of the almost or quite divided 4–6-petalous imbricate corolla, alternate with them, attached to the very base; ovary 2–6-celled; cells with 1 ovule; stigma almost sessile, lobed; fruit succulent, with 2–6 stones; seeds suspended, with copious fleshy perisperm; radicle superior.—Illustrative Genera: *Ilex*, L.; *Prinos*, L.

Affinities, &c.—The affinities of Aquifoliaceæ to Ebenaceæ and Sapotaceæ have been noticed under those Orders. Some authors consider them related to Rhamnaceæ or Celastraceæ; but their sympetalous corolla, want of disk, straight embryo, and their relations to Ebenaceæ, as well as the difference in the ovary and seeds, remove them from the immediate neighbourhood of those Orders. On the other hand, they exhibit some approach to Loganiaceæ and Apocynaceæ.

Distribution.—A small Order, widely scattered, but sparingly. *Ilex Aquifolium*, the Holly, is the only European species.

Qualities and Uses.—The bark is ordinarily astringent and tonic, and that of the Common Holly is esteemed a febrifuge; its berries produce emetic and purgative action; its leaves and still more those of *Ilex paraguayensis*, called Maté or Paraguay Tea, resemble Tea in property, as is the case also with *Prinos glabra*, a North-American shrub. Other species of *Ilex* are also used for this purpose in South America. The viscid substance called Bird-lime is made from the bark of the Holly; and its close white wood is valued by cabinet-makers.

STYRACACEÆ are remarkable among the Orders here placed near it for the inconstancy of the character dependent on the adhesion of the calyx; Miers divides it into two, Symplocaceæ and Styracaceæ, separated by this mark, by the æstivation of the corolla, and other points. It is commonly regarded as related to Ebenaceæ among the Corollifiorals, and also to Aurantiaceæ and Ternstrœmiaceæ among the Thalamiflorals; while Lindley connects it with Celastraceæ through Sapotaceæ: others point out a resemblance to Philadelphaceæ.

Distribution.—Scattered sparingly in the warm regions of Asia and America.

Qualities and Uses.—Bitter and aromatic, sometimes containing a pungent resin. Gum Benzoin is obtained from *Styrax Benzoin* in the Malay

archipelago; Storax from *St. officinale* in Syria; other species yield similar resins. *Symplocos* furnishes dyes or mordants; the leaves of *S. tinctoria* (Sweet-leaf, or Horse-sugar, North America) are sweet, and are eaten by cattle. *Halesia tetraptera*, another North-American plant, is called the Snowdrop tree on account of its numerous white bell-shaped blossoms.

The following Orders, sometimes placed in this subdivision, are of doubtful position, or rather their affinities are very various:—OLACACEÆ constitute an Order of tropical trees and shrubs, often climbers, apparently nearly related to Santalaceæ, but having distinct, rarely united, petals and a free ovary. The stamens are frequently superposed to the petals. —ICACINACEÆ, separated from the preceding by Miers and Eichler, have the stamens alternate with the petals. In both the æstivation of the petals is valvate; while CYRILLACEÆ, a group of American shrubs, have imbricate petals and a disk surrounding the ovary; they are placed next Aquifoliaceæ by Bentham and Hooker.—HUMIRIACEÆ are tropical American trees or shrubs with balsamic juice, free petals, and monadelphous stamens, each having an enlarged fleshy connective: they appear to be related to the Olacaceæ and Linaceæ, having also affinities to the Styracaceæ and Aurantiaceæ. The systematic position and, in some cases, the exact limitations of these groups is unsettled; as is also that of CANELLACEÆ, a little group of plants connected with Clusiaceæ by some authors, by others with Olacaceæ and their allies, placed by Bentham and Hooker near Bixaceæ and Violaceæ, but more nearly allied in structure and bitter aromatic properties to Magnoliaceæ.

Series 3. DICARPIÆ.

Ovary usually superior. Stamens alternate and isomerous with the lobes of the corolla or fewer. Carpels 2, rarely 1–3. The typical formula is $\widehat{S\,5} \mid \widehat{P\,5}\ A\ 5\ \widehat{G\,2}$.

OLEACEÆ. THE OLIVE AND ASH ORDER.

Coh. Jasminales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs with opposite and pinnate or simple leaves; flowers with a 4-cleft (or sometimes obsolete) calyx; a regular 4-cleft or nearly or quite 4-divided, hypogynous corolla, the lobes of which are valvate in the bud, or sometimes apetalous; stamens 2–4, mostly 2, and fewer than the lobes of the corolla (figs. 408, 409); ovary 2-celled, with 2 suspended ovules in each cell: fruit fleshy or capsular, often 1-seeded by abortion; seeds with abundant fleshy perisperm; radicle superior.—Illustrative Genera: Tribe 1. OLEÆ. *Fruit fleshy.* Olea, *Tournef.* Tribe 2. FRAXINEÆ. *Fruit dry, sometimes samaroid.* Fraxinus, *Tournef.*

Fig. 408.

Fig. 409.

Fig. 408. Diagram of flower of Lilac (*Syringa*): *x*, bract; *a*, *a*,

Affinities, &c.—The relations of this Order are rather obscure. Some authors connect them with the Jasminaceæ; but although some of the genera approach that Order in structure, they appear to be distinct in their valvate corolla, adnate (dorsifixed) anthers, pendulous ovules, and the nature of the perisperm. They are also related to Apocynaceæ and Rubiaceæ. The Salvadoraceæ are also to be regarded as a neighbouring family. Lindley thought the Order allied to Solanaceæ.

Distribution.—A small Order, the members of which are chiefly found in temperate climates.

Qualities and Uses.—The most important plant of the Order is the Olive (*Olea europæa*), so largely cultivated for the bland oil expressed from the fleshy pericarp. *Ornus europæa*, *O. rotundifolia*, and *Fraxinus excelsior* have a sweet juice which hardens into the substance called Manna. *Fraxinus excelsior* is the common Ash-tree, so valuable for its tough wood; it only produces Manna in a warmer climate than Britain; its bark, as well as that of the Olive and Garden Lilac (*Syringa vulgaris*), has decided febrifuge qualities. The leaves of the Ash act like senna. The flowers of *Olea fragrans* were formerly used in China to flavour Tea. This Order contains several of the commonest flowering shrubs of our gardens, the Lilac (*Syringa*), Privet (*Ligustrum*), *Phillyrea*, *Chionanthus*, &c.

JASMINACEÆ.—The Jasmine Order consists of shrubs, often with twining stems; leaves opposite or alternate, mostly compound; calyx and corolla hypogynous, 5–8-parted, corolla imbricated in the bud; stamens 2, projecting from the tube of the corolla; ovary superior, 2-lobed, 2-celled, with 1–4 erect ovules in each cell; fruit a berry or capsule; seeds with little or no perisperm, radicle inferior.—Illustrative Genera: *Jasminum*, L.; *Nyctanthes*, Juss.

Affinities, &c.—This Order is distinguished from the Oleaceæ by the imbricated æstivation of the corolla, the erect ovules, and the small quantities of perisperm in the seeds, besides the number of the organs in the floral envelopes, which is seldom a multiple of the stamens: most authors place it near Oleaceæ, others near Apocynaceæ and Ebenaceæ; but Lindley thinks it has little connexion with them, and really approaches more closely to Verbenaceæ.

Distribution.—The Order is not very extensive; the major part of the plants are East-Indian; a few occur scattered, two even in South Europe.

Qualities and Uses.—The leaves and roots appear to possess a certain acridity; but the most remarkable quality is the fragrance of the flowers of many kinds, from the presence of a volatile oil. *Jasminum officinale*, *J. grandiflorum*, and *J. Sambac* especially yield this. *Nyctanthes Arbor-tristis* is also exceedingly fragrant, but in the night-time only; its corollas yield an orange dye.

SALVADORACEÆ are a small Order of shrubs or small trees with opposite leathery leaves, panicled small flowers; calyx, corolla, and stamens 4-merous, hypogynous; ovary superior, 1–2-celled; stigma sessile; ovule 1–2, erect; fruit fleshy, 1-seeded, and the seed without perisperm.—It is related by its 4-nary structure to Oleaceæ and to Plantaginaceæ, having a membranous corolla like the last; also resembling

Plumbaginaceæ in habit. Baillon points out an affinity to Celastraceæ.—The species are found in India, Asia Minor, and North Africa. The most important is *Salvadora persica*, supposed to be the Mustard-tree of the Bible, its fleshy fruit having an aromatic odour and tasting like garden-cress. The bark of its root is used in India as a vesicatory. The leaves of *S. indica* are purgative.

LOGANIACEÆ.

Coh. Gentianales, *Benth. et Hook.*

Diagnosis.—Trees, shrubs, or herbs with opposite leaves and interposed stipules sometimes reduced to an elevated line or a ridge; calyx 4–5-cleft; corolla hypogynous, gamopetalous, regular, 4-, 5-, or 10-cleft, valvate or contorted or imbricated in æstivation; stamens springing from the corolla; ovary superior, usually 2-celled; style divided above into as many lobes as the cells of the ovary; ovules numerous or solitary; fruit capsular, 2-celled, with the placentas finally detached, drupaceous, with 1- or 2-seeded stones, or baccate with the seeds immersed in pulp; seeds with a straight embryo in fleshy or cartilaginous perisperm, sometimes winged, mostly peltate; embryo straight, radicle inferior.

ILLUSTRATIVE GENERA.

Tribe 1. GELSENIEÆ. *Corolla-lobes imbricate; style bifid; stigmas lateral; fruit capsular.* Gelsenium, *Juss.*

Tribe 2. EU-LOGANIEÆ. *Style simple; stigma terminal; ovules numerous in each cell of the ovary.* Spigelia, *L.*; Buddleia, *L.*; Desfontainea, *Ruiz et P.*; Usteria, *Willd.*; Strychnos, *L.*

Tribe 3. GÆRTNEREÆ. *Style bifid; cells of ovary* 1-*ovulate; corolla-lobes valvate.* Gærtnera, *L.*

Affinities, &c.—This Order was formerly associated with Apocynaceæ and the neighbouring Orders; but, as remarked by Bentham, it consists, on the whole, of Rubiaceæ with a free ovary, at the same time approaching, by certain of its diverse forms, some of the genera of several of the Corollifloral Orders even more nearly than the general mass approach Rubiaceæ. To Apocynaceæ, which are very near in general structure, some genera, such as *Geniostoma*, which has contorted æstivation of the corolla, and *Mitrasacme*, where the carpels are partially distinct below and united above, approach very closely; *Mitrasacme* and *Mitreola* were formerly arranged as doubtful Gentianaceæ, and *Fagræa* and *Potalia* approach still more nearly, the former greatly resembling *Lisianthus* in character, while *Buddleia* and its allies have been referred to Scrophulariaceæ until lately, but are brought into this Order by Bentham, since they cannot be separated from *Logania*. The main difference from Apocynaceæ lies in the stipules; but these are sometimes reduced to a mere line connecting the leaves: the peculiar stigma of that Order affords another means of separating them; and the Apocynaceæ often have hypogynous glands, which the Loganiaceæ have not. From Gentianaceæ the distinction lies generally in the stipules and the axile placentation; occasionally the succulent condition of the fruit is required as a decisive mark. From the Scrophulariaceæ the stipules,

the regular corolla, the agreement of the number of stamens and lobes of the corolla, and quincuncial æstivation divide Loganiaceæ in most cases; and although the æstivation and the regular corolla occur sometimes in the former Order, there are then usually alternate leaves and no stipules. As observed by Bentham, this is hardly so much a Natural Order as a receptacle for anomalous forms of several really natural groups, Rubiaceæ, Apocynaceæ, Gentianaceæ, &c.

Distribution.—A rather large group, the species of which are chiefly tropical, but some are found in North America and Australia.

Qualities and Uses.—The plants belonging to this Order have mostly powerful poisonous properties, in particular the genus *Strychnos*. *S. Nux-vomica* bears the seeds known by its name, so noted for the presence of Strychnia. *S. toxifera* is said to furnish the active ingredient of the celebrated Woorali poison of Guiana. *S. cogens* is likewise used to poison arrows in Central America. *S. Tieuté* (the bark of the root) yields the Java poison called Upas Tieuté. Many seem to be free from strychnia as regards the bark; for that of *S. Pseudoquina* is used as a substitute for Cinchona in Brazil, that of *S. Nux-vomica* also, and the wood of *S. ligustrina*, called Lignum colubrinum. *S. potatorum*, an East-Indian species, is called the Clearing-nut; and it is said that, when its seeds are rubbed round in a vessel containing muddy water, it causes the impurities to settle. The seeds from the Philippines, known as St. Ignatius's Beans, have been described as the seeds of a plant called *Ignatia amara*; but are probably those of an unknown *Strychnos*, perhaps *multiflora*, which grows on those islands. The species of *Spigelia* are acro-narcotic; *S. marilandica*, the Carolina Pink-root, and *S. Anthelmia* are used as vermifuges, but are somewhat dangerous, sometimes producing spasms and even convulsions. *Potalia amara* is bitter, acrid, and emetic.

GENTIANACEÆ. The Gentian Order.

Coh. Gentianales, *Benth. et Hook.*

Diagnosis.—Smooth herbs, with a bitter juice, opposite and sessile, mostly simple, entire, and strongly ribbed leaves, without stipules; flowers regular, with a persistent calyx, with stamens as many as the lobes of the usually withering-persistent corolla, and which are convolute (rarely imbricated, and sometimes valvate) in the bud; ovary 1-celled, with two parietal placentas, projecting more or less toward the centre; the fruit mostly a 2-valved, septicidal, many-seeded capsule, sometimes with a fleshy pericarp; seeds small; embryo minute in the axis of fleshy perisperm.

Illustrative Genera.

Tribe 1. Exaceæ. *Corolla-lobes contorted dextrorse; ovary 2-celled.* Exacum, *L.*

Tribe 2. Chironieæ. *Corolla-lobes dextrorse; ovary 1-celled.* Chironia, *L.*

Tribe 3. Swertieæ. *Corolla-lobes contorted or imbricate; ovary 1-celled; style short.* Gentiana, *L.*

Tribe 4. MENYANTHEÆ. *Leaves radical or alternate; corolla-lobes induplicate-valvate; ovary* 1-*celled.* Menyanthes, *L.*; Villarsia, *Vent.*

Affinities, &c.—This Order stands very near Apocynaceæ, from which it differs in its placentation and completely coherent carpels, habit, want of milky juice, and other points. The parietal placentas distinguish it from the Scrophulariaceæ and allied Orders, which sometimes show an approach to the regular structure of Gentianaceæ. Gesneraceæ differ in their irregular flowers, axile embryo, and other characters. An affinity exists to Orobanchaceæ, especially through *Obolaria*, a N.-American plant formerly referred to that Order, *Voyra*, a parasitic leafless genus, and some allied forms lately discovered in South America, while *Crawfurdia*, a twining genus, seems to connect the Gentianaceæ with Convolvulaceæ.

Distribution.—A large Order, generally diffused—the large genus *Gentiana* especially inhabiting the mountains of temperate and hot climates, but not in polar regions.

Qualities and Uses.—Bitter, tonic properties are general; a few are emetic or narcotic, especially when fresh. Among the bitter kinds medicinally employed are the Gentians, *G. lutea* (officinal), *punctata*, *purpurea*, *pannonica*, all European, *G. Catesbæi* (U.S.), *G. Kurroo* (Himalaya), *Frasera Walteri* (U.S.), *Agathotes Chirayita*, a native of the Himalayas. *Erythræa Centaurium*, *Menyanthes trifoliata*, *Chlora perfoliata*, *Gentiana campestris* and *Amarella*, all British herbs, have been used in the same way. The plants of this Order mostly have beautiful flowers, brilliant blue predominating, but red, white, and purple, and more rarely yellow occurring. The Gentianella of our gardens is *G. acaulis*; and the smaller Gentians are among the most beautiful of Alpine plants. *Villarsia nymphæoides* is an elegant water-plant occurring in Britain. *Limnanthemum*, an exotic genus, is also aquatic.

APOCYNACEÆ. DOG-BANE.

Coh. Gentianales, *Benth. et Hook.*

Diagnosis.—Plants with milky acrid juice, entire (mostly opposite) leaves, without stipules; flowers regular, 5-merous and 5-androus; the 5 lobes of the corolla convolute and twisted in the bud; the filaments distinct, springing from the corolla, and the pollen granular; ovary 2- or more rarely 1-celled, composed of 2 carpels more or less coherent in the ovarian and stylar region and quite blended in the drum-shaped or dumb-bell-shaped stigma; ovules numerous; fruit 1 or 2 follicles, a capsule, drupe, or berry; seeds mostly with fleshy or cartilaginous perisperm, often with a tuft of hairs at the top.

ILLUSTRATIVE GENERA.

Tribe 1. CARISSEÆ. *Anthers free; ovary entire.* Allamanda, *L.*

Tribe 2. PLUMIERIEÆ. *Anthers free, without appendages; ovaries free; styles united.* Vinca, *L.*

Tribe 3. ECHITIDEÆ. *Anther-cells with appendages at the base; ovaries free; styles united.* Nerium, *L.*

Affinities, &c.—Related closely to some Loganiaceæ and to Gentianaceæ, as noticed under those Orders—also to Asclepiadaceæ, from which they are chiefly distinguished by the freedom of the stamens from the stigma and by the granular pollen. The thickened stigma, however, and appendaged anthers found here indicate a close relationship. *Alyxia* has ruminate perisperm.

Distribution.—A large group, the species of which are chiefly tropical, a few scattered in temperate climates. *Vinca* occurs in Britain.

Qualities and Uses.—Often violent poisons, acting as drastic purgatives and emetics, sometimes with a narcotic influence. Not a few, however, have delicious edible fruits; and the bark of some is tonic and febrifuge. The milky juice contains Caoutchouc, in some cases sufficient to become commercially valuable. The poisonous principles appear to occur chiefly in the seeds and in the milky juice. The seeds of *Tanghinia venenifera*, the Madagascar Poison-nut, are very deadly, as are also the seeds of *Cerbera*, *Thevetia*, *Cameraria latifolia* (the Bastard Manchineel), the stem, root, leaves, and flowers of *Nerium* (the Oleander), *Echites*, *Plumiera*, &c. Where somewhat milder, as in *Apocynum* and *Allamanda*, the plants are occasionally available medicinally, but only in small doses. *Wrightia antidysenterica*, some species of *Carissa*, *Hancornia pubescens*, and others are simply bitter and febrifuge, like Gentians. The succulent fruits of *Hancornia speciosa* (Brazil), *Carissa Carandas* and *edulis* (East Indies), *Roupellia grata* (Sierra Leone), are not only harmless, but very delicious. Caoutchouc is obtained from *Urceola elastica*, *Willughbeia edulis* (East Indies), *Vahea gummifera* (Madagascar), *Collophora utilis* *Cameraria latifolia* (South America), also from species of *Landolphia* and *Hancornia*. The milky juice of *Tabernæmontana utilis*, the Cow-tree of Demerara, is innocuous and nutritious. *Wrightia tinctoria* furnishes a kind of indigo; and the wood of species of *Wrightia* (East Indies), *Aspidosperma* (Guiana), &c. is valuable as timber. The bark of *Alstonia scholaris* is recommended as a tonic and antiperiodic. This Order furnishes some of our most beautiful stove-plants—*Echites*, *Allamanda*, *Dipladenia*, *Nerium*, *Plumiera*, &c. forming striking ornaments in every extensive horticultural collection.

ASCLEPIADACEÆ.

Coh. Gentianales, *Benth. et Hook.*

Diagnosis.—Shrubs or herbs, often twining, with milky juice, opposite or whorled (rarely scattered) entire leaves without stipules: flowers regular, 5-merous, 5-androus, the lobes of the corolla mostly valvate; filaments springing from the corolla-tube, united into a tube, and often prolonged beyond and behind the anther into horn-like processes constituting the corona; carpels 2, distinct, or coherent below; stigmas coherent into a 5-angled fleshy head, to which the anthers are adherent (fig. 410); pollen coherent into wax-like or granular masses; ovaries with numerous ovules on the

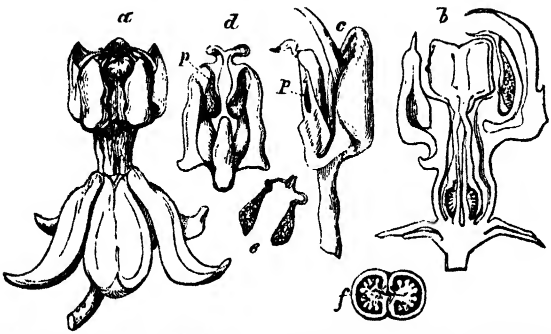
sutures; fruit a pair of follicles, or by abortion 1; seeds mostly with a crown of hairs at the hilum, with thin perisperm.

ILLUSTRATIVE GENERA.

Suborder 1. PERIPLOCEÆ. *Pollen granular; anthers acuminate.* Periploca, *L.*

Suborder 2. ASCLEPIADEÆ. *Filaments united into a tube; pollen in waxy coherent pollinia.* Asclepias, *L.*; Hoya, *R. Br.*; Stapelia, *L.*

Fig. 410.



a, Flower of *Asclepias purpurascens*; *b*, a vertical section, with the petals removed; *c*, side view of a stamen; *d*, inside view of an anther (*p*, pollen-sac); *e*, two pollen-masses; *f*, cross section of the ovary.

Affinities, &c.—The genera are further grouped into tribes and subtribes, according to the nature of the anthers and pollinia. The curious organization of the stigma and pollen is the great distinguishing feature of this Order, which in other respects is closely allied to Apocynaceæ. When the pollen is mature, it escapes in "pollen-masses" from the anthers (fig. 410, *e*), and adheres to gelatinous processes developed on the sides of the stigma, which retain it, so that it can push its pollen-tubes into the lateral and inferior stigmatic surfaces; after fertilization, the stigma with the adherent anthers and filaments separate from the style and leave a pair of distinct carpels, which ripen (one or both) into free follicles.

Distribution.—A large Order, mostly tropical, in Asia, Africa, and America; one or two species occur in Europe, and a few in North America.

Qualities and Uses.—Generally resembling the Apocynaceæ; but the active properties are not so much developed, and the succulent fruits do not appear here. Species of *Asclepias, Cynanchum, Calotropis* (Mudar), *Tylophora,* and *Periploca* are more or less emetic or purgative; the leaves of *Solenostemma Arghel* and *Gomphocarpus fruticosus* are frequent adulterations in Alexandrian Senna, and are said to cause griping. The roots

of *Hemidesmus indicus* are used as a substitute for Sarsaparilla. The milky juice of *Cynanchum ovalifolium* yields Caoutchouc at Penang. *Marsdenia tenacissima* and *Orthanthera viminea*, East-Indian plants, afford very tenacious fibre; *Marsdenia tinctoria* a kind of Indigo. The *Stapeliæ* and *Ceropegiæ* are remarkable for their succulent habit; some of them form curious tubers, as *Brachystelma*. *Hoya* partakes of the succulent habit, but has wax-like leaves and blossoms, sometimes very handsome. *Dischidia* is remarkable for its pitcher-leaves. *Gymnema lactifera* is the Cow-plant of Ceylon, which yields a milky juice, harmless and nutritious, and which is used by the natives as food.

HYDROPHYLLACEÆ form a small Order, allied in some respects to Boraginaceæ, but differing in their one-celled many-seeded ovary with parietal placentation, which also separates them from Polemoniaceæ, with which they have many points of agreement. They are chiefly natives of the north and extreme south of America. Their properties are unimportant; but species of some of the genera, as *Nemophila*, *Eutoca*, &c., are interesting and showy garden plants, grown with us as tender annuals. Hydroleads are sometimes separated from this Order by reason of their distinct styles and anatropous ovules.

DIAPENSIACEÆ consist of two genera, *Diapensia* and *Pyxidanthera*, each having one species. They are connected with Convolvulaceæ by some authors, but appear to stand between Hydrophyllaceæ and Polemoniaceæ, having a 3-celled ovary like the latter, and a filiform embryo with very short cotyledons, approaching that of the former. They are very closely allied to Ericaceæ, but the anthers do not open by pores.

POLEMONIACEÆ (THE PHLOX ORDER) consists of herbs with alternate or opposite leaves, regular 5-merous and 5-androus flowers, the lobes of the corolla mostly convolute (sometimes imbricated) in æstivation; ovary 3-celled, style 3-lobed; the capsule 3-celled, 3-valved, few- or many-seeded; valves usually breaking away from a triangular central columella; seeds perispermic; embryo straight; cotyledons elliptical, foliaceous.—Illustrative Genera: *Phlox*, L.; *Polemonium*, Tournef.; *Cobæa*, Cav.

Affinities, &c.—One of the smaller Orders; it is remarkable for its 3-celled ovary. It is nearly related to Convolvulaceæ, *Cobæa* agreeing even in the climbing habit; the ovary equally distinguishes it from these, the Hydrophyllaceæ, and the Gentianaceæ, to all of which it has close affinity. From Diapensiaceæ it differs in the regular calyx and insertion of the stamens, as well as in the embryo. The seeds are remarkable in many cases for hairs upon the testa containing a spiral fibre; in *Collomia* these expand elastically when wetted; in *Cobæa* they are short, broad, and firm.—The Polemoniaceæ occur most abundantly in the temperate regions of North and South America. *Polemonium cæruleum*, Greek Valerian or Jacob's Ladder, grows in the north of England, and is common in gardens. The other genera furnish some of the favourite tender perennial and annual herbaceous plants of our gardens. They have no important properties.

CONVOLVULACEÆ. The Bindweed Order.

Coh. Convolvulales, *Benth. et Hook.*

Diagnosis.—Chiefly twining or trailing herbs, sometimes leafless and parasitic, or shrubby and erect, often with some milky juice; with alternate leaves (or scales); flowers regular, 5-androus; calyx of 5 imbricated sepals, the 5-plaited or 5-lobed corolla convolute or twisted in the bud; ovary 2-celled (rarely 3-celled), or with 2 separate pistils, with 2 erect ovules in each cell, the cell sometimes doubled by a false partition between the seeds, thus falsely 4-celled; embryo large, curved or coiled in mucilaginous perisperm, with foliaceous cotyledons, or (*Cuscuteæ*) filiform and coiled with the cotyledons scarcely perceptible; radicle inferior.—Illustrative Genera: *Convolvulus*, L.; *Cuscuta*, Tournef.

Fig. 411

Fig. 412.

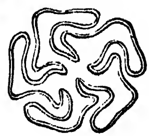


Fig. 411. Funnel-shaped corolla of *Convolvulus.*
Fig. 412. Plicate æstivation of the corolla of *Convolvulus.*

Affinities, &c.—This Order approaches the regular sympetalous Boraginaceæ, Polemoniaceæ, and allied Orders; the structure of the ovary separates it from the first, the curved embryo and the fruits from the second. Cordias also differ in their aperispermic seeds and superior radicle. Some of the Convolvulaceæ are of shrubby habit, and depart widely from the appearance with which we are most familiar. *Cuscuta* is sometimes made the type of a distinct Order; but the parasitical habit is not a sufficient character.

Distribution.—A large Order, of which a few species occur in temperate climates, but the majority belong to the tropics.

Qualities and Uses.—A purgative property generally characterizes these plants, among which are several yielding important medicinal substances. True Jalap is the root of *Exogonium Purga*, Scammony of *Convolvulus Scammonia*; *Pharbitis cathartica* and *Ipomœa tuberosa* yield a similar substance. The white hedge-Convolvulus (*Calystegia sepium*) has a similar action, as also various *Ipomœæ* and *Convolvuli*, the active matter being a kind of resin existing in the milky juice. The seeds of *Pharbitis Nil* (semen Kaladanæ) and *P. cærulea* are also used as purgatives. On the other hand, *Ipomœa edulis* forms a large fleshy tuber, which is widely cultivated and eaten under the name of the Sweet Potato, and *Ipomœa macrorhiza* has edible farinaceous roots. The twining and trailing plants of this Order are mostly remarkable for the beauty of their flowers, and many of them are cultivated; the garden Major Convolvulus is *Pharbitis purpurea*, the blue Minor Convolvulus is *Convolvulus tricolor*. *Convolvulus arvensis*, Bindweed, grows everywhere, on the ground, rooting at the nodes; *C. Soldanella* grows in like manner on the sea-shore; *Calystegia*

sepium, the White Convolvulus, is one of our most beautiful and at the same time commonest hedge-plants.—The *Cuscuteæ* or "Dodders" are remarkable for their leafless and parasitic habit; they germinate in the ground, and then coil themselves round the stems of plants and send roots in through their rind, by which they are then entirely nourished. They have wire-like stems with minute scales at the nodes, and tufts of small Convolvulaceous flowers. They are great pests in clover- and flax-fields, destroying the plants they infest.

SOLANACEÆ. Nightshades.

Coh. Polemoniales, *Benth. et Hook.*

Diagnosis.—Herbs, rarely shrubs or trees, with colourless juice and alternate leaves; flowers regular, or slightly irregular, often extra-axillary, 5-merous and 5-androus, on bractless pedicels; corolla hypogynous, plaited-imbricate, plaited-convolute, or involutive-valvate in æstivation; stamens epipetalous; ovary 2-celled, cells antero-posterior; fruit a 2-celled (rarely 3–5-celled) many-seeded capsule or a succulent berry. Seeds perispermic; embryo curved.

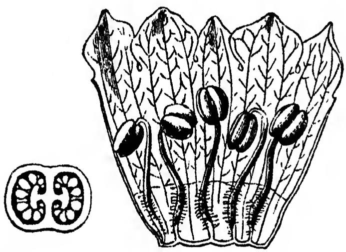
Fig. 413.

Deadly Nightshade (*Atropa Belladonna*).

Character.

Thalamus **flat.** ***Calyx*** **free, or rarely 4- or 6-cleft, persistent, or the upper part separating by transverse dehiscence, mostly growing somewhat during the ripening of the fruit (accrescent).** ***Corolla*** **gamopetalous, 5- or rarely 4- or 6-parted or toothed, rotate, campanulate, funnel- or salver-shaped, sometimes obliquely irregular, plaited-imbricate, plaited-convolute, or involutive-valvate in the bud.** *Stamens* springing from the tube of the corolla, equal in number to its lobes and alternate with them ; *filaments* sometimes rather unequal ; *anthers* 2-celled, with the

Fig. 414.



a, Corolla of *Atropa Belladonna*, showing the attachment of the stamens ; *b*, cross section of the ovary.

cells sometimes connate above, dehiscing longitudinally or by terminal pores. *Ovary* usually 2-celled, the carpels anteroposterior ; placentas axile, sometimes enlarged into spurious dissepiments, rendering the ovary 4-celled ; ovary rarely 3–5-celled by increased number of carpels ; *ovules* numerous ; *style* simple ; *stigma* simple or lobed. *Fruit* capsular, with septicidal or transverse dehiscence (fig. 294), or a succulent or dryish indehiscent berry (fig. 301) ; *seeds* numerous, the embryo mostly slender and curved, sometimes straight, with foliaceous cotyledons in fleshy perisperm.

ILLUSTRATIVE GENERA.

Petunia, *Juss.*	Hyoscyamus, *Tournef.*	Solanum, *L.*
Nicotiana, *Tournef.*	Physalis, *L.*	Atropa, *L.*
Datura, *L.*	Capsicum, *Tournef.*	Mandragora, *Tournef.*

Affinities, &c.—A considerable range of variation in the condition of most of the organs upon which a character is founded renders it difficult to circumscribe this Order strictly ; in fact it passes by almost insensible gradations into the Scrophulariaceæ. Generally speaking, the Solanaceæ

are distinguished by the plaited æstivation of the corolla, equality of the number of stamens with the lobes of the corolla, and a curved embryo from the Scrophulariaceæ, which have imbricated æstivation, stamens fewer than the lobes of the corolla, and a straight embryo; but none of

Fig. 415.

Henbane (*Hyoscyamus niger*).

these characters are constant in the former Order; yet the nearly regular corolla and five perfect stamens will in almost all cases distinguish the Solanaceæ. Miers has proposed, in extension of a suggestion of R. Brown, to establish a new Order, Atropaceæ, to include the aberrant forms of Solanaceæ and Scrophulariaceæ, and leave these better defined—the brief diagnoses of these Orders being:—

1. Solanaceæ. Stamens equal in number to the lobes of the corolla (or petals), whose æstivation is valvate or induplicate-valvate.—2. Atro- [illegible] Stamens equal in number to the lobes of the corolla (or

petals), one sometimes sterile; æstivation of the corolla imbricated, or some modification of imbricated.—3. SCROPHULARIACEÆ. Stamens less in number than the lobes of the corolla (or petals), 4 or 2; æstivation of the corolla imbricated.

This arrangement is, however, not adopted by Bentham and Hooker, who make five tribes of this order, viz.:—Solaneæ, Atropeæ, Hyoscyameæ, Cestrineæ, and Salpiglossideæ. The removal of the *Buddleieæ* to Loganiaceæ, as proposed by Bentham, however, is favourable to this arrangement, as it removes the 4-androus genera with regular 4-lobed corollas, which would render the above diagnosis of Scrophulariaceæ faulty. The Solanaceæ, as a whole, have, however, closer relations with some of the regular gamopetalous Orders, particularly with Hydrophyllaceæ and Convolvulaceæ; they are connected with Boraginaceæ by *Grabowskia*, a Brazilian genus, formerly regarded as a *Lycium*, which has the habit of the latter with the ovary of Boraginaceæ: it is nearly related to *Nolana*. According to Lindley, *Cestrum* connects the Solanaceæ with the Oleaceæ, through *Syringa*; but although it has a straight embryo with foliaceous cotyledons, the radicle is inferior, not superior, and the resemblance appears to exist chiefly in habit. Polemoniaceæ differ in their 3-celled ovary and straight embryo.

Distribution.—A very large Order, the members of which are generally distributed, and most abundantly in the tropics.

Qualities and Uses.—The genera referable to Atropaceæ, as indicated above, are mostly characterized by narcotic poisonous properties. The Solanaceæ are apparently less powerful, and certain kinds furnish wholesome and some important articles of food; but many of them possess narcotic properties. Some have an acrid quality; some have diuretic action; and others are accounted tonics. Among the poisonous kinds the most important are:—the *Atropa Belladonna* (Deadly Nightshade, which has the curious property of relaxing the iris, and thus causing dilation of the pupil, as also does *Anthocercis viscosa*); *Datura Stramonium* (the Thorn-apple), and *D. Metel, Tatula, ferox, alba*, &c.; *Hyoscyamus niger* (Henbane), and other species; *Nicotiana Tabacum, persica*, and *rustica* (the American, Persian, and Syrian Tobacco-plants); *Mandragora officinalis* (the Mandrake), *Acnathera venenata*, a Cape shrub, said to be more deadly than any of them. The foliage of some species of *Solanum* is said to have active properties of the same kind, especially *S. nigrum* (Black Nightshade), *S. Dulcamara* (Bitter-sweet or Woody Nightshade), and even the leaves and stems of *S. tuberosum* (the common Potato) and *Physalis somnifera*. *Solanum Pseudo-quina* is employed in Brazil as a substitute for Cinchona. Some species of *Cestrum*, as *laurifolia* and *Pseudo-quina*, are said to have similar properties. Other *Cestra*, as *C. euanthes*, *lævigatum*, &c., many species of *Physalis*, *Solanum*, &c., are accounted diuretic. The natives of central Australia chew the leaves of Pitury, *Duboisia Hopwoodii*, as a stimulant. It has similar properties to Coca (p. 234), and dilates the pupil.

The species of *Capsicum* are remarkable for the pungent quality of the fruits, the common Capsicum being the produce of *C. annuum*, and Cayenne pepper consisting of the powdered seeds of various species, such as *C. frutescens*. While some of the plants are such active poisons in all parts,

others are only partially or not at all so. The berries as well as the foliage of *Atropa*, for example, and the seeds and capsules as well as the foliage of *Hyoscyamus*, are very deadly; but the succulent fruits of many species of *Solanum* are wholesome, as the Egg-Apple or Aubergine (*S. Melongena*), those of *S. laciniatum*, eaten in Australia under the name of Kangaroo Apples, &c., and, it is said (but this wants confirmation), those of the *S. nigrum*, *Dulcamara*, and others. *Lycopersicum esculentum*, the Tomato, is another example. Still more striking appears the instance of the Potato, at first sight; but it must be remembered that the edible tuber is an artificial product, and consists chiefly of cellular tissue and starch developed under circumstances that *oppose* the formation of the noxious secretion; and what is present may be dissipated by heat. It is said that the poisonous element of Solanaceous fruits exists in a pulpy covering of the seeds, not in the pericarp. It is desirable that this point should be ascertained.

CORDIACEÆ constitute an Order, chiefly consisting of tropical plants, combined with Boraginaceæ by Bentham and Hooker, from which, however, they differ in the twisted æstivation of the corolla and the plaited cotyledons. From Convolvulaceæ they differ in their superior radicle and the absence of perisperm. The Order is remarkable for the plaited cotyledons of the embryo.—The fruits of *Cordia Myxa* and *latifolia* are called Sebestens or Sebesten plums, and, with those of other species, are edible.

are a small group of South-American plants, referred by Bentham and Hooker to Convolvulaceæ, by others to Boraginaceæ, sometimes erected into a distinct Order on account of the valvate calyx, plaited regular corolla, the ovary of 5–20 carpels, either distinct, or when numerous combined into several sets, seated on a fleshy disk, with a single style and stigma; the embryo curved, in little perisperm. The chief distinction from Boraginaceæ lies in the 5-merous ovary and the absence of the scroll-like inflorescence; they may be regarded as aberrant forms of that Order. Some species of *Nolana* are cultivated in gardens for their showy flowers, somewhat resembling blue *Convolvuli*. Their properties are unknown.—Genera: *Nolana*, L.; *Alona*, Lindl.

BORAGINACEÆ. THE BUGLOSS ORDER.

Coh. Polemoniales, *Benth. et Hook.*

Diagnosis.—Chiefly roughly hairy herbs (not aromatic), with alternate entire leaves, a scorpioid inflorescence usually without bracts, and symmetrical flowers with a 5-parted calyx, an hypogynous, regular (rarely slightly irregular) 5-lobed corolla, 5 stamens springing from the corolla-tube; ovary of two carpels, each deeply 4-lobed, the lobes surrounding the base of the single gynobasic style, and forming when ripe 4 indehiscent 1-seeded achenes in the bottom of the persistent calyx; stigma simple or bifid; seeds separable from the pericarp, aperispermic; radicle superior.

Fig. 416.

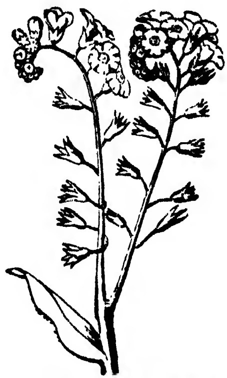
Persistent calyx of a Boraginaceous plant, opened to show the fruit formed of four indehiscent carpels, separating from each other.

Illustrative Genera.

Echium, *L.*	Symphytum, *L.*	Lithospermum, *L.*
Borago, *Tournef.*	Anchusa, *L.*	Myosotis, *L.*

Affinities, &c.—The floral formula is $\widehat{S5} \mid \widehat{P5}\ A\,5\ \widehat{G2}$. The 4-lobed ovary and fruit of this Order agree exactly with those of the Labiatæ, in which the irregular corolla, didynamous stamens, opposite leaves, and square stems differ widely. This character of the ovary does not occur in any other regular 5-androus gamopetalous Order. The Nolanaceæ and Ehretiaceæ depart from the general type of this Order. Ehretiaceæ seem to bear the same relation to the proper Boraginaceæ as the Verbenaceæ to Labiatæ, having confluent carpels, terminal styles, and a shrubby or arborescent habit. The corolla mostly presents a coronet of scales in the throat, which some incline to regard as abortive stamens. The bractless inflorescence of some of the genera is remarkable. The inflorescence, whether with or without bracts, is probably a uniparous scorpioid cyme, though it has been considered to be an inflorescence of "partition."

Fig. 417.



Scorpioid cyme of *Myosotis palustris.*

Distribution.—A large Order, the species of which are mostly natives of temperate climates in the northern hemisphere.

Qualities and Uses.—The plants of this Order, remarkable for their rough foliage, have a reputation as mucilaginous and cooling herbs. Their chief importance lies in the dye furnished by the roots of *Anchusa tinctoria* (Alkanet) and various species of *Echium*, *Onosma*, &c., and the beauty of their flowers, whence the genera above cited include many common garden plants. The Forget-me-not is a native species of the genus *Myosotis.* Many Boraginaceæ occur wild with us.

consist of a group of plants included in Boraginaceæ by Bentham and Hooker, but separated by some authors on account of the coherence of the carpels and the terminal style (which is gynobasic in true Boraginaceæ) and a drupaceous fruit. Some genera have perisperm, others not. They seem to be as distinct here as Verbenaceæ from the Labiatæ; but the agreement is very close at some points in both cases. They are also nearly related to the Cordiaceæ; but the latter have twisted æstivation and plaited cotyledons.—Most of them are tropical trees or shrubs. None are of much importance: the drupes of some *Ehretiæ* are eaten; the Heliotrope (*Heliotropium peruvianum*) is universally known for its delicious odour.—Genera: *Ehretia,* L.; *Tournefortia,* R. Br.; [illegible]*n,* L., &c.

LABIATÆ.

Coh. Lamiales, *Benth. et Hook.*

Diagnosis.—Chiefly herbs, with square stems and opposite aromatic leaves; flowers with a more or less 2-lipped, hypogynous corolla, didynamous or diandrous stamens; deeply 4-lobed ovary, the lobes surrounding the base of the single gynobasic style, and forming, when ripe, 4 indehiscent 1-seeded achenes in the bottom of the persistent calyx; stigma bifid; seeds erect, with little or no perisperm.

Character.

Thalamus flat or slightly elongated, often prolonged into a hypogynous disk or series of glands. *Calyx* inferior, persistent, tubular, 5-merous, with the odd sepal posterior; the limb regularly 5- or 10-toothed, or irregular and bilabiate (fig. 418), 3- to

Fig. 420.

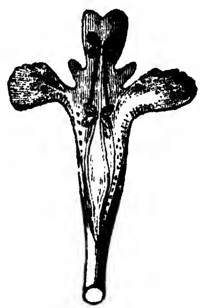


Fig. 419.

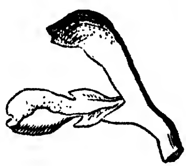


Fig. 418.

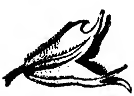


Fig. 418. Calyx of *Salvia*. Fig. 419. Corolla of *Salvia*.
Fig. 420. Corolla of *Glechoma* opened, showing the didynamous stamens.

10-toothed. *Corolla* hypogynous, gamopetalous, bilabiate; the upper lip entire or divided, arched or almost suppressed; the lower lip usually larger and 3-lobed (fig. 419). *Stamens* springing from the corolla, 4, didynamous (fig. 420), or sometimes 2; *anthers* 2-celled or apparently 1-celled from the apposition of the cells at the apex, or with the filament or connective bifurcate and bearing either 2 single cells or 1 perfect cell and a sterile process. *Ovary* deeply 4-lobed, on a fleshy disk, 4-celled, each cell with 1 erect ovule; *style* simple, arising from the bottom of the carpels; *stigma* forked. *Fruit* composed of 4, or, by abortion, 3, 2, or 1, dry, separable, 1-seeded portions, surrounded by the persistent calyx; *seeds* with little or no perisperm; cotyledons flat; radicle inferior.

Illustrative Genera.

Lavandula, *L.*	Thymus, *L.*	Marrubium, *L.*
Mentha, *L.*	Hyssopus, *L.*	Ballota, *L.*
Salvia, *L.*	Prunella, *L.*	Phlomis, *L.*
Rosmarinus, *L.*	Lamium, *L.*	Teucrium, *L.*
Origanum, *L.*	Stachys, *Benth.*	Ajuga, *L.*

Affinities, &c.—A large and well-marked order, divided by Bentham into eight tribes, according to the number, position, and direction of the fertile stamens. The genera are founded on variations in the calyx and corolla, &c. As regards the structure of its ovary, this Order agrees exactly with Boraginaceæ, from which, however, almost all its other characters distinguish it. The ordinary structure is $S\,5 \mid \widehat{P\,5}\,\widehat{A\,4}\,\widehat{G\,2}$, as for all Orders with didynamous stamens. Among the didynamous unsymmetrical monopetalous Orders, no other group approaches this structure but Verbenaceæ, which are distinguished by the greater degree of coherence of the carpels and the terminal style, as the Ehretiaceæ are from Boraginaceæ; but the separation of these Orders is sometimes difficult. Disregarding the ovary, the character of the corolla and stamens connects Labiatæ with Scrophulariaceæ and its allies, especially when they have opposite leaves and square stems. The morphology of the corolla and stamens is very interesting in this Order, as it is in the Scrophulariaceæ; the didynamous structure arises from the want of the posterior stamen, and in the diandrous genera it is the anterior pair that remains. Payer says there are originally five stamens in Labiates, two anterior first developed, then two lateral, while the fifth or posterior is the last to appear, and indeed is often suppressed or present in the shape of a gland. The anterior first-born stamens are the longest and their anthers open first. The foliage of the majority of plants in this Order is studded with microscopic glandular hairs, containing the essential oils to which they owe their remarkable fragrance. Various species of *Salvia* have hairs upon the testa of the seed, containing a spiral fibre, somewhat as in Polemoniaceæ.

Distribution.—A very large Order, the species of which are principally natives of temperate climates; but the more fragrant kinds occur most abundantly in the warm temperate and drier regions.

Qualities and Uses.—The most striking qualities of this Order depend upon the presence of aromatic or fragrant essential oils, which render some of them valuable stimulants and antispasmodics, others favourite flavouring herbs for culinary purposes, others important ingredients in perfumes, &c. Some are also regarded as tonics. The fleshy subterraneous rhizomes of *Stachys palustris* are sometimes cultivated as a table vegetable; and the tubers of an *Ocimum* are said to be eaten in Madagascar. Of the carminative aromatics, the Mints, Spearmint (*Mentha viridis*), Peppermint (*M. Piperita*), Penny-royal (*M. Pulegium*) are among the best known. Other species of *Mentha* have similar properties; *Hedeoma pulegioides*, the Penny-royal of the United States; Lavender, *Lavandula vera*; together with the inferior French Lavender, *L. Spica*, the oil of which, however, is chiefly used in the arts (oil of Spike), and others: many allied

species are used in different countries in the same way. The essential oils of some kinds commonly used as flavouring herbs are also used in veterinary medicine. Among the best-known of these, besides Mint, are Thyme (*Thymus Serpyllum* and other species), Marjoram (*Origanum*, various species), Basil (*Ocimum* sp.), Savory (*Satureia* sp.), Sage (*Salvia officinalis* and *grandiflora*), &c. As perfumes, Lavender, Patchouli (*Pogostemon Patchouli*), *Mentha citrata*, Rosemary (*Rosmarinus officinalis*), and others are largely used. Horehound (*Marrubium vulgare*) is an old-fashioned remedy for coughs; Ground-ivy (*Nepeta Glechoma*), Balm (*Melissa officinalis*), and others are used by the country-people for the same complaints. *Monarda fistulosa* (a North-American shrub) and *Origanum Dictamnus* (or Dittany of Crete) are reputed febrifuges. *Stachys Betonica* has been regarded as a sternutatory, but perhaps acts mechanically: its root is said to be purgative and emetic; but this seems unlikely to be true.

Many plants of this Order decorate our gardens, and many species are wild in Britain.

VERBENACEÆ (THE VERVAIN ORDER) consists of herbs, shrubs, or trees, with opposite or alternate leaves; flowers with an hypogynous more or less 2-lipped or irregular corolla and didynamous stamens; style terminal; the 2-4-celled fruit dry or drupaceous, usually splitting when ripe into as many 1-seeded, indehiscent nucules; seeds erect or pendulous, with little or no perisperm.—Illustrative Genera: *Verbena*, L.; *Tectona*, L.; *Clerodendron*, L.; *Vitex*, L.; *Phryma*, L.; *Stilbe*, Berg.; *Myoporum*, Bks. & Sol.; *Avicennia*, L.; *Ægiphila*, Jacq.

Affinities, &c.—Principally distinguished from Labiatæ by the terminal style and more coherent carpels. The *Myoporeæ*, kept separate by Bentham and Hooker, can hardly be separated from the *Verbeneæ* except by the presence of two seeds in each cell of the ovary, and by the superior radicle; and perhaps Selaginaceæ should be appended as an aberrant form. The structure of the fruit separates this Order from Scrophulariaceæ and its allies.

Distribution.—A large Order, chiefly tropical; the *Verbeneæ* common in temperate South America, and a few scattered in all regions. The *Avicenniæ* grow, like Mangroves, in tropical salt marshes.

Qualities and Uses.—Those of the *Verbeneæ* are much the same as in Labiatæ: *Aloysia citriodora*, the cultivated "Lemon-plant," or "Verbena," is an instance of fragrant properties; many species of *Lantana* are fragrant or fœtid; some are used as substitutes for Tea. *Vitex Agnus-castus*, *V. Negundo*, and others have acrid fruits. *Tectona grandis* is the East-Indian Teak-tree, celebrated for its hard heavy wood (African Teak is from a Euphorbiaceous tree). The bark of *Avicennia tomentosa*, the White Mangrove of Brazil, is used for tanning. Clerodendrons are handsome stove-shrubs. The brilliant Verbenas of our gardens are mostly varieties of *Verbena chamædrifolia* and allied species.

SELAGINACEÆ form a small group differing from Verbenaceæ principally in having 1-celled anthers; in *Globularia* the carpels are reduced to one.

Hence there appears a connexion between them and Salvadoraceæ, which approach Verbenaceæ and *Ehretieæ* among the Boraginaceæ in other points. Some of the plants are European; most of them belong to the Cape. *Globulariæ* have purgative and emetic properties.—Genera: *Selago*, L.; *Globularia*, L.

ACANTHACEÆ.

Coh. Personales, *Benth. et Hook.*

Herbs or shrubs with opposite or whorled simple exstipulate leaves; flowers irregular, bracteated, with an imbricated hypogynous more or less 2-lipped corolla, didynamous or diandrous stamens attached to the tube of the corolla; fruit a 2-celled, 4–12-seeded capsule; seeds anatropous, aperispermic, usually flat, supported by hooked or cup-shaped projections of the placentas; radicle inferior.—Illustrative Genera: *Thunbergia*, L.; *Ruellia*, L.; *Barleria*, L.; *Acanthus*, L.; *Adhatoda*, Nees; *Justicia*, L.

Affinities, &c.—This Order is closely related to Scrophulariaceæ and Bignoniaceæ, differing from the former in the aperispermic seeds, from the latter chiefly, so far as written characters can be given, in the structure of the placenta and in the seeds not being winged. Generally speaking, the large bracts of the inflorescence, and the imbricated calyx of unequal sepals, give a peculiar and characteristic appearance to these plants. The seeds of *Acanthodium*, *Ruellia*, and other species have a testa clothed with curious compound hairs containing spiral fibres. By Bentham and Hooker, following Anderson, the Order is divided into five tribes, viz. *Thunbergieæ*, *Nelsonieæ*, *Ruellieæ*, *Acantheæ*, and *Justicieæ*. The distinctions are founded upon the nature of the calyx, the æstivation of the corolla, the characters afforded by the seeds, &c.

Distribution.—A large Order, chiefly tropical.

Qualities and Uses.—Mostly without active properties. The most striking peculiarity lies in the beauty of the flowers of many kinds, which renders them great favourites in our stoves. *Acanthus mollis* is interesting from its leaves having, it is said, furnished the model of the Corinthian capital. *Andrographis paniculata* is used as a bitter tonic.

BIGNONIACEÆ (THE TRUMPET-FLOWER ORDER) consists of woody, or rarely herbaceous plants, often twining or climbing, with exstipulate leaves, hypogynous sympetalous corollas, didynamous or diandrous stamens; the ovary commonly 2-celled, by the meeting of the 2 placentas or of projections from them, surrounded at the base by a disk; many-seeded; the seeds large, winged, with a flat embryo, and no perisperm.—Illustrative Genera: *Bignonia*, L.; *Tecoma*, Juss.; *Catalpa*, Scop.; *Eccremocarpus*, R. & P.

By Bentham and Hooker the order is divided into four tribes, *Bignonieæ*, *Tecomeæ*, *Jacarandeæ*, and *Crescentieæ*; the latter often treated as a separate Order. The points of distinction are the number of cavities in the ovary, the nature of the fruit, the erect or climbing habit, &c.

Affinities, &c.—The aperispermic character of the seeds separates this Order from Scrophulariaceæ. From Acanthaceæ there is less marked distinction; but the winged and sessile seeds, together with the general habit of the inflorescence, mark the difference. *Eccremocarpus* approaches closely to Gesneraceæ; and these, with Pedaliaceæ and Crescentiaceæ, are chiefly separated by the want of coherence of the placentas in the axis (the exceptional case here in *Eccremocarpus*) and the absence of a wing to the seeds. Many Bignoniaceæ are remarkable for the structure of their woody stems, which have the wood divided into segments by broad wedged-shaped processes of the bark; the segments are 4 in young stems, forming a cross in the transverse section; 8, and even 16 lobes appear in the woody layers of subsequent years. The broad paper-like wing of the seeds of *Bignoniæ* has a very elegant microscopic structure.

Distribution.—A considerable family of mostly tropical plants; the Trumpet-flowered climbers form striking features of American forests.

Qualities and Uses.—Many of the plants of this Order are used in Brazil for various purposes, such as dyes, medicines of varied action, timber, &c.; but none are of very great importance. Their beautiful flowers, often large and brightly coloured, render them very attractive. *Tecoma radicans*, *Eccremocarpus scaber*, &c. are common garden climbers; *Catalpa syringæfolia* is a handsome tree with showy blossoms, hardy in this country.

PEDALIACEÆ are chiefly distinguished from Bignoniaceæ by their generally wingless seeds, and by their different habit. *Sesamum* may be regarded as intermediate between the Orders just named, while *Martynia* establishes a transition to Gesneraceæ, of which Order Pedaliaceæ, or, as they are sometimes called, Sesameæ, are considered by some to form a tribe.—They are chiefly tropical; the most important member of the group is *Sesamum orientale*, which is an object of cultivation in the East for its seeds, from which oil resembling Olive-oil is obtained. Some of the species are in cultivation, among them one or two species of *Martynia* remarkable for the two long horns to the fruit.

Æ are also very near to the Gesneraceæ, and chiefly distinguished by the arborescent habit and large amygdaloid seeds; the calyx also is free, and its limb splits irregularly. From Pedaliaceæ the fruits and the amygdaloid seeds divide them. The indehiscent fruit and wingless seeds separate them from Bignoniaceæ and Acanthaceæ, and this, together with the want of perisperm, from Scrophulariaceæ, Solanaceæ, and Lentibulariaceæ.—This Order is tropical, most developed in the Mauritius and Madagascar.—*Crescentia Cujete*, the Calabash-tree, has a fruit like a gourd, with a hard shell applicable to many useful purposes, holding liquids, forming floats for rafts, &c. The subacid pulp is eaten. *Parmentiera cerifera* (Panama) has a long slender fruit, and is called, from the shape of this, the Candle-tree; it is a favourite food of cattle.

GESNERACEÆ.

Coh. Personales, *Benth. et Hook.*

Diagnosis.—Soft woody shrubs or herbs, somewhat succulent, with opposite or whorled wrinkled leaves, without stipules; flowers irregular; corolla perigynous or hypogynous, sympetalous: stamens diandrous or didynamous with a rudimentary 5th; ovary half-superior, with a ring of glands or a disk, 1-celled, with two 2-lobed parietal placentas; fruit capsular or succulent; seeds numerous, with or without perisperm; cotyledons much shorter than the radicle.

ILLUSTRATIVE GENERA.

Suborder 1. *with a little perisperm; calyx partly "adherent" to the capsular fruit.*

Gesnera, *Mart.*
Achimenes, *P. Br.*
Gloxinia, *Hérit.*

Suborder 2. CYRTANDREÆ. *Seeds without perisperm; fruit free, capsular, twisted, or baccate.*

Æschynanthus, *Jack.*
Streptocarpus, *Lindl.*
Cyrtandra, *Forst.*

Affinities, &c.—The Gesneraceæ have much the aspect of Scrophulariaceæ; and the flowers very much resemble those of Bignoniaceæ, but their placentas are decidedly parietal; and although *Eccremocarpus* connects them with Bignoniaceæ, its winged seeds and large cotyledons still mark the difference from Gesneraceæ. The parietal placentas resemble those of Orobanchaceæ, which connect the Order further with Scrophulariaceæ; but in the *Gesnereæ*, where the seeds are perispermic, the calyx is more or less adherent to the ovary. In *Streptocarpus* it sometimes happens that one of the two cotyledons becomes persistent and enlarged, forming the only leaf formed by the plant.—They are tropical plants, the *Gesnereæ* American; the *Cyrtandreæ* more diffused, but chiefly Eastern. They are of no great importance as regards their properties; some have edible fruits: the most interesting point about them is the beauty of the flowers. Most of the genera above cited are found in collections of stove-plants; in their native habitations they are often epiphytic.

COLUMELLIACEÆ consist of a few species of Mexican or Peruvian plants, which have been supposed to approach Jasminaceæ, or still more closely to Gesneraceæ and Rubiaceæ; but their structure is not well made out. In many respects they are nearly allied to *Escallonieæ* in Saxifragaceæ. They have an adherent calyx, epigynous corolla, two stamens with sinuous anthers, and an inferior 2-celled ovary with numerous ovules. Seeds perispermic; embryo minute.

OROBANCHACEÆ (BROOM-RAPES) are fleshy herbs destitute of green foliage (root-parasites); corolla sympetalous; stamens irregular, hypogynous, didynamous; the ovary 1-celled, with 2–4 parietal placentas; capsule with very numerous seeds, which are minute, perispermic, with a very small rudimentary embryo.—Illustrative Genera: *Orobanche*, L.; [illegible]*a*, L.

Affinities, &c.—This Order is especially remarkable for the parasitic habit, the fleshy texture, scale-like leaves, and the absence of chlorophyl, in which particulars the plants resemble Monotropaceæ; but these are not characters of ordinal value, and we see them running into the nearest allies of this group, as *Buchnera* and *Striga* in Scrophulariaceæ, not to mention the partially parasitic condition of *Melampyreæ*. The Order is chiefly separated from Scrophulariaceæ by its parietal placentas. From Gentianaceæ it differs in the carpels being placed back and front, $\overset{\circ}{\underset{\circ}{+}}$, as in Scrophulariaceæ and the allied Orders, while in Gentianaceæ they are right and left of the axis, $\circ + \circ$. From Gesneraceæ there is little except the habit to separate them.—These plants are parasitic on the roots of many herbs and shrubs of very various orders; they attach themselves immediately after germination, and become organically grafted; some increase by tuberous buds from the base of the annual stems. The Orobanchaceæ are bitter and astringent, and are said to be escharotic; these qualities probably depend on a resinous fluid secreted in the abundant epidermal hairs. They are comparatively numerous in Europe, North America, North Asia, and the Cape; some in India.

SCROPHULARIACEÆ.

Coh. Personales, *Benth. et Hook.*

Diagnosis.—Chiefly herbs; flowers with hypogynous, sympetalous, irregular corollas, the lobes of which are imbricate in æstivation; didynamous, diandrous (or very rarely 5 perfect) stamens springing from the tube of the corolla; ovary 2-celled, cells antero-posterior; fruit a 2-celled, mostly many-seeded capsule with axile placentas; seeds anatropous; embryo small, in copious perisperm.

Character.

Thalamus flat, oblique, or provided with annular disk or gland. *Calyx* persistent, more or less deeply 3–5-toothed, more or less irregular. *Corolla* sympetalous, irregular; the tube long or short; the limb more or less deeply 5-lobed, or 4-lobed by the coherence of the 2 posterior petals, personate (fig. 422), bilabiate, rotate (fig. 421), sometimes spurred. *Stamens* 2, 4, and didynamous (fig. 425), or with the 5th (posterior) perfect, sterile, or represented by a petaloid tooth (fig. 423), attached to the corolla; *anthers* 2-celled, or 1-celled by confluence or by suppression. *Ovary* 2-celled, with axile placentas bearing usually numerous ovules; *style* and *stigma* simple, or bifid at the apex. *Fruit* capsular, rarely baccate, 2-celled, dehiscing by 2 or 4 valves, or by pores, or indehiscent; *seeds* mostly numerous, perispermic.

Fig. 421.

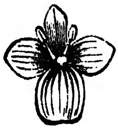


Fig. 423.

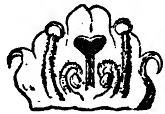


Fig. 425.

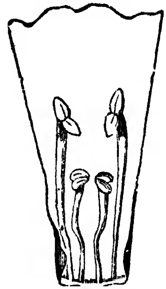


Fig. 422.

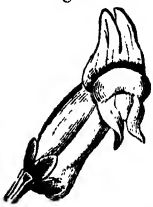


Fig. 424.

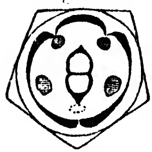


Fig. 421. Corolla and stamens of *Veronica*.
Fig. 422. Calyx and corolla of *Antirrhinum*.
Fig. 423. Corolla, laid open, with didynamous stamens and staminode, of *Scrophularia*.
Fig. 424. Diagram of flower of *Scrophularia*.
Fig. 425. Didynamous stamens of *Digitalis*.

Illustrative Genera.

This large Order exhibits considerable variety of conditions, whence its affinities become somewhat complex. It is by Bentham and Hooker divided into three Suborders or Series, thus:—

1. Pseudosolaneæ. *Leaves alternate; inflorescence centripetal, two posterior lobes of corolla outside.* Verbascum, *L.*
2. Antirrhineæ. *Leaves sometimes opposite; inflorescence centripetal. Corolla bilabiate, imbricate in æstivation, the posterior lobe outside the anterior one.* Calceolaria, *Feuill.*; Linaria, *L.*; Antirrhinum, *L.*; Scrophularia, *L.*; Gratiola, *L.*
3. Rhinantheæ. *Æstivation imbricate, the two lateral lobes or one of them placed outside.* Digitalis, *L.*; Euphrasia, *L.*

Affinities, &c.—The near connexion with Solanaceæ, shown in the close relationship between *Salpiglossis* and *Petunia*, is mentioned also under that Order, where a reference is made to the proposed transfer of the *Salpiglossidæ* to the Order Atropaceæ of Miers. Mr. Bentham defines the present Order by referring to Solanaceæ the genera which have at once 5 stamens and a corolla plaited in æstivation; *Petunia* has a plaited corolla and 5 stamens, which, however, are unequal and declinate, and thus approach to *Salpiglossis*, where the corolla is very similar, but the stamens truly didynamous. *Verbascum*, having 5 stamens, is sometimes referred to Solanaceæ; but one at least of the stamens is commonly sterile, and its corolla is imbricated. In another direction, Scrophulariaceæ approach some of the forms of the very heterogeneous Loganiaceæ; and Bentham regards it as advisable to refer *Buddleia* and its allies, generally

counted among Scrophulariaceæ, to that Order, as the only means of setting a definite boundary between the Orders, these genera having a transverse ridge connecting their opposite leaves—an indication of the characteristic interpetiolar stipules of Loganiaceæ. With Orobanchaceæ, again, the connexion is close, especially through the root-parasitism of many genera, all of which approach closely in the general structure of the flower to *Orobanche*; for the carpels are really anterior and posterior in that Order as they are here, and the main distinction is, that the margins are not folded-in to form a dissepiment, so that Orobanchaceæ have parietal instead of axile placentation, to which is added their minute rudimentary embryo. A general resemblance exists between the present Order and the other didynamous gamopetalous Orders; but Gesneraceæ, Pedaliaceæ, and Crescentiaceæ have parietal placentas; Bignoniaceæ and Acanthaceæ have aperispermic seeds, and Lentibulaceæ a free central placenta.

The morphology of the corolla in this Order is well deserving of attention: curious monstrosities not unfrequently occur in cultivation, in which the normal irregularity is obliterated by a repetition of the pouches, spurs, or similar developments in each constituent petal, as in *Linaria*, where a 5-spurred corolla occurs with a symmetrical limb (Pelorian variety)—in this instance the regularity is due to the increased number of the usually irregular parts; in other cases the flower becomes perfectly regular by the complete absence of pouches and spurs. *Calceolaria* sometimes occurs with a somewhat campanulate, regular corolla, &c. Many of the Scrophulariaceæ are parasitic upon the roots of other plants, as, for example, *Melampyrum*, *Rhinanthus*, and their allies, which, however, appear to be only partly nourished in this way, having distinct roots; they are remarkable for turning black when dried; *Striga*, an exotic genus, is still more distinctly parasitical; and *Buchnera hydrabadensis* has scale-like leaves similar to those of *Orobanche*. In some of the genera (*Mimulus* &c.), where the style is divided at the apex, it is developed into two flat laminæ, which exhibit irritability. Chatin says that the stamens appear simultaneously, and that it is only after birth that the irregularity in number and form becomes manifest; but that does not accord with our observations. The probability is that the development varies in different genera. *Pentstemon heterandrum* has the fifth stamen antheriferous.

Distribution.—A very large group, the species of which are universally diffused and very abundant.

Qualities and Uses.—More or less acrid, or bitter; mostly unwholesome; sometimes deadly poisons. *Digitalis purpurea*, our native Foxglove, the officinal plant, is an extremely powerful sedative poison, both in the foliage and the seeds; the allied species *D. lutea*, *ochroleuca*, *lævigata*, &c. are equally active. The species of *Verbascum* have a share of this property, especially in the seeds. The *Scrophulariæ*, *Linariæ*, and *Veronicæ* are all more or less bitter and acrid, and suspicious; *Gratiola* is violently purgative and emetic.

This Order is remarkable for the number of beautiful flowering herbs it contains. The Snap-dragon, or Dragon's-mouth (*Antirrhinum majus*), the species of *Veronica*, *Mimulus* (of which the Musk-plant, *M. moschatus*, is remarkable, among plants of this order, for its fragrance), *Linaria*, *Pentstemon*, *Calceolaria*, *Maurandya*, &c. are in every garden; and of their

numerous exotic allies a long list will be found in all horticultural collections. A large number of showy-flowered native weeds belong to this Order, such as the Toad-flax (*Linaria vulgaris*) and several other species of *Linaria*, the Speedwells (*Veronica*), the Red Rattle (*Pedicularis*) and the Yellow Rattle (*Rhinanthus*) (so called from the ripe seeds rattling in the dried inflated membranous capsules), the Foxglove, Mulleins (*Verbascum*), &c.

LENTIBULARIACEÆ (Butter-worts) are small herbs growing in water or wet places; flowers with a 2-lipped calyx and a 2-lipped personate spurred corolla; stamens 2, with (confluent) 1-celled anthers; ovary 1-celled, with a free central placenta bearing several anatropous seeds, with a thick straight embryo and no perisperm; stigma bilabiate.—Illustrative Genera: *Utricularia*, L.; *Pinguicula*, Tournef.

Affinities, &c.—This Order is interesting both from the habit and appearance of the plants and from its affinities:—on the one hand with the irregular, didynamous gamopetalous Orders, through Scrophulariaceæ, with which it agrees in the calyx, corolla, and stamens, and on the other hand with the regular Sympetalæ, through Primulaceæ, with which it is connected by the free central placenta. Dickson says the thalamus in development begins to show irregular growth before there is any appearance of the parts of the flower, and that the pistil is 5-carpous; the embryo is sometimes mono- in other species dicotyledonous. The structure of the leaves of the *Utriculariæ*, especially that of their pouches or air-floats (fig. 427), is very curious. Pringsheim considers these pouches to be dilatations of a branch.—The plants are found in all parts of the globe; the *Utriculariæ* are aquatic, one curious Brazilian species (*U. nelumbifolia*) growing in the water retained in the axils of the sheathing leaves of a *Tillandsia*. In *Utricularia* the radicle aborts and the adult plant is rootless; the submerged capillary branches have often been mistaken for leaves or roots. The pitchers of *Utricularia* and the leaves of *Pinguicula* have alike the property of dissolving and absorbing animal matter, such as insects, &c. *Pinguiculæ* are bog-plants; and *P. vulgaris* is said to have the property of coagulating milk.

Fig. 426.

Fig. 427.

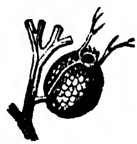


Fig. 426. Flower of *Utricularia*.
Fig. 427. Air-sac of the leaf of *Utricularia*.

Division III. **Apetalæ or Incompletæ.**

Dicotyledonous plants with a green or coloured calyx and no petals, or with a calyx-like perianth of more than one whorl, or with the floral envelopes reduced to one or more bract-like pieces, or altogether absent. Flowers often unisexual.

Exceptions, &c.—The above characters are more or less artificial, and

bind together a rather heterogeneous series of orders. Many of them are merely degraded forms of Thalamifloral or Calycifloral types. The group is sometimes divided into two subdivisions, called Monochlamydeæ and Achlamydeæ, according as there is or is not a true calyx or perianth surrounding the stamens and pistil. A double floral envelope occurs in some Euphorbiaceæ, Loranthaceæ, &c. Many of the plants in this group have unisexual flowers grouped in cones or catkins.

Series 1. Superæ.

Ovary superior; perianth usually distinct.

POLYGONACEÆ. The Sorrel Order.

Coh. Chenopodiales, *Benth. et Hook.*

Diagnosis.—Herbs with alternate leaves, mostly furnished with stipules in the form of sheaths (*ocreæ*) above the swollen joints of the stem; the flowers mostly perfect, with a more or less persistent perianth; stamens hypogynous, or rarely perigynous; a 1-celled ovary bearing 2–3 styles or stigmas, and a single erect orthotropous ovule; fruit a triangular nut enclosing 1 erect seed, usually with farinaceous perisperm and an inverted embryo.—Illustrative Genera: *Eriogonum*, L. C. Rich; *Rheum*, L.; *Polygonum*, L.; *Coccoloba*, Jacq.; *Rumex*, L.

Affinities, &c.—The commoner plants of this Order may be distinguished by the peculiar ocreaceous stipules (fig. 65), which, however, are wanting in *Eriogonum* and some other genera; the most distinctive characteristic is the solitary erect seed with its embryo having the radicle turned upward; this separates it from its near allies, the Chenopodiaceæ and Amarantaceæ, from which also the perianth and the ocreæ remove it; also from the Nyctaginaceæ, to which the involucrate flowers and abortive stipules of *Eriogoneæ* approach. There is a further relation to Caryophyllaceæ through the Paronychiaceæ. The Order is divided into tribes according to the bi- or unisexual flowers, the presence or absence of an involucre, the number of the parts of the flower, the presence of an ocrea, &c.

Distribution.—A large Order, the members of which are universally diffused; especially abundant in temperate climates.

Qualities and Uses.—The foliage of these plants is frequently characterized by the presence of an acid juice, depending on the presence of oxalic and malic acids, or by an acrid, pungent juice; some are strongly astringent, while the roots are generally more or less powerfully purgative; the starchy perisperm of the seeds is sufficiently abundant in some species to furnish a valuable substitute for corn. Among the useful acidulous kinds are the garden Rhubarb, *Rheum undulatum*, *R. palmatum*, &c.; the Sorrels (*Rumex scutatus*, *R. Acetosa*, and *R. Acetosella*) are familiar plants. *Rheum Ribes* is used for flavouring sherbet in the East; and some other exotic plants have like properties. *Polygonum Hydropiper*, a common native

weed, is very acrid, even vesicant when fresh. *P. Bistorta* was formerly in use as an astringent; and *Coccoloba uvifera*, the sea-side Grape of the West Indies, furnishes a very astringent extract. The Rhubarb of medicine consists of the roots of *Rheum officinale*, and perhaps also of *palmatum, undulatum, rhaponticum, Emodi, Webbianum*, and other species; the roots of *Rumex alpinus* were formerly used as a purgative under the name of Monk's Rhubarb. *Fagopyrum esculentum*, common Buck-wheat, *F. tataricum*, and other species are largely cultivated for food in the northern parts of Asia and of Eastern Europe. The common Docks are species of *Rumex*.

NYCTAGINACEÆ (THE MARVEL-OF-PERU ORDER) consists of herbs, shrubs, or trees, mostly with opposite and entire leaves; stems tumid at the joints; flowers surrounded by an involucre, with a delicate, tubular or funnel-shaped petaloid perianth; upper part deciduous, lower part persistent, constricted above the 1-celled, 1-seeded ovary, and indurated to form the pericarp (diclesium); stamens 1 or several, slender, hypogynous; the embryo coiled round the outside of the mealy perisperm, with broad foliaceous cotyledons and an inferior radicle.—Illustrative Genera: *Boerhaavia*, L.; *Mirabilis*, L.; *Pisonia*, Plum.

Affinities, &c.—The nearest relatives of these plants are probably the Polygonaceæ, especially the tribe of *Eriogoneæ*; but the inferior radicle and the peculiar fruit enclosed in the indurated base of the perianth are evident distinctions. The stems of these plants, especially of the *Pisoniæ*, have a curious arrangement of their fibro-vascular bundles. The nature of the involucre serves to divide the Order into tribes.

Distribution.—Natives of warm climates, chiefly in the S. hemisphere.

Qualities and Uses.—The roots of the Nyctaginaceæ are generally purgative; and *Mirabilis Jalapa* was formerly supposed to be the source of medicinal Jalap. *Mirabilis dichotoma*, the Marvel of Peru of our gardens, is remarkable for opening its flowers in the afternoon, whence it is termed the Four-o'clock Plant; both this and *M. longiflora*, another cultivated species, are violent purgatives. *Bougainvillea* is remarkable for its brightly-coloured bracts.

AMARANTACEÆ (AMARANTHS) are weedy herbs, with opposite or alternate exstipulate leaves, and spiked or capitate, bracteated inflorescence; the flowers mostly with an imbricated perianth of dry and scarious persistent bracts, often coloured, 3–5 in number; occasionally unisexual; stamens 5-merous, hypogynous; anthers sometimes 1-celled; the one-celled ovary usually 1-ovuled, in one tribe (Celosieæ) many-ovuled; style 1 or 0; stigma simple or compound; fruit a utricle, a caryopsis, or a berry; seed pendulous, with the embryo curved round the circumference of farinaceous perisperm; the radicle near the hilum.—Illustrative Genera: *Celosia*, L.; *Amarantus*, L.; *Achyranthes*, L.; *Gomphrena*, L.

Affinities, &c.—No absolute character can be given to separate this Order from the Chenopodiaceæ; but the habit, especially the crowded bracteated inflorescence and the membranous perianth, renders them very different in appearance. Their more distant relations are the same as those of that Order. The division into tribes depends upon the 1- or 2-celled anthers and the number of ovules in the ovary.

Distribution.—A large Order, the species of which are most abundant within the tropics, in dry, barren situations.

Qualities and Uses.—Generally with somewhat mucilaginous juice, seldom with active properties. The species of *Amarantus*, such as *A. caudatus*, Love-lies-bleeding, and *A. hypochondriacus*, Prince's-Feathers, are well known in gardens for their bright-coloured and persistent blossoms—as are also the more tender Globe Amaranthus (*Gomphrena*) and the Cock's-comb (*Celosia cristata*), the latter remarkable for its fasciated flowering-stem.

CHENOPODIACEÆ. The Spinach Order.

Coh. Chenopodiales, *Benth. et Hook.*

Diagnosis.—Chiefly herbs, of weedy aspect, more or less succulent; leaves mostly alternate; without stipules or scarious bracts; flowers perfect, polygamous or diclinous, minute, greenish, the free perianth imbricated in the bud; stamens as many as the perianth-lobes, or rarely fewer, and inserted in front of them or on their bases; ovary 1-celled, becoming a 1-seeded thin utricle or an achænium; embryo coiled into a ring (around the perisperm when present) or spiral.—Illustrative Genera: *Salicornia*, Tournef.: *Atriplex*, L.; *Blitum*, L.: *Beta*, Tournef.: *Chenopodium*, L.; *Salsola*, L.

Affinities, &c.—Closely related to Amarantaceæ, but differing in habit and in the sum of the characters. From the Phytolaccaceæ they differ in the simple ovary and the stamens equal in number and opposite to the segments of the perianth; from *Scleranthеæ* they are separated by the simple ovary, the usually alternate leaves, and the distinctly hypogynous condition of the stamens: from the *Paronychieæ* particularly by the absence of stipules; through the Paronychiaceæ they are nearly related to Caryophyllaceæ. The order is divided into two groups according as the embryo is annular or spirally coiled.

Distribution.—A large Order, generally diffused in waste places or in salt marshes; most abundant outside the tropics.

Qualities and Uses.—Generally bland and innocuous, the foliage often rendering them valuable as pot herbs, and their roots furnishing food for cattle; sometimes with anthelmintic and antispasmodic properties. The maritime kinds were formerly of great value from the quantity of soda obtained from their ashes. Spinach (*Spinacia oleracea*), Orach (*Atriplex hortensis*), and English Mercury (*Chenopodium Bonus Henricus*) belong to this Order; also the Beet and Mangold Wurtzel (*Beta vulgaris* and *Cycla*). From the juice of the Beet, sugar is extracted in considerable quantities. *Chenopodium anthelminticum* yields an essential oil, used as an anthelmintic under the name of Worm-seed Oil; *C. ambrosioides* and *Botrys* also have an aromatic, antispasmodic essential oil; *Chenopodium Quinoa* forms tubers like potatoes, which are eaten in Peru. *Salsola Soda*, *Salicornia herbacea*, and other species (Glass-wort), with species of *Atriplex*, *Schoberia*, &c.,

abound in salt marshes, and were formerly much used in the preparation of barilla. Several species of *Chenopodium* and *Atriplex* abound in waste places, forming, with various kinds of Dock (*Rumex*), *Polygonum*, and *Urtica* (Nettle), the most conspicuous weeds of neglected cultivated ground.

BASELLACEÆ are a small Order of plants closely related to Chenopodiaceæ, chiefly distinguished by the presence of a double, coloured perianth and perigynous stamens: they are tropical climbing herbs or shrubs. Some species of *Basella* are used as Spinach; *Ullucus tuberosus* has a tuberous root, used in Peru like the Potato.

PHYTOLACCACEÆ proper are nearly connected with Polygonaceæ and Chenopodiaceæ, differing from both in the frequent presence of petals and of a number of carpels, from the former also in the absence of stipules, from the latter in the stamens exceeding the lobes of the perianth. *Phytolacceæ* pass into *Petiverieæ* by the occurrence of 5 separate carpels in *Gieseckia*, while *Rivinia* has little perisperm; the *Petiverieæ* would then connect this Order with the Sapindaceæ and their allies, while the columella of the *Gyrostemoneæ* would mark a distant affinity with the Malvaceæ.—A small Order, scattered in all parts of the world, with properties more or less acrid, purgative, or emetic.

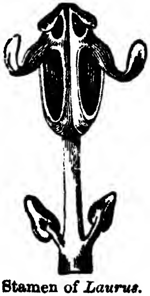
PARONYCHIACEÆ, sometimes placed in this group, are treated of previously near Caryophyllaceæ.

PETIVERIEÆ, separated by some authors, have stipulate leaves, single ovary, aperispermic seeds, and a straight embryo with convolute cotyledons; and GYROSTEMONEÆ have exstipulate leaves, unisexual flowers, the carpels arranged round a columella, twin suspended ovules, perispermic seeds, with a hooked embryo having linear cotyledons, and an inferior radicle. The last two orders are included under Phytolaccaceæ by Le Maout and Decaisne.

LAURACEÆ. THE LAUREL ORDER.

Coh. Laurales, *Benth. et Hook.*

Fig. 428.



Stamen of *Laurus*.

Diagnosis.—Aromatic trees or shrubs, with alternate simple exstipulate leaves, sometimes marked with pellucid dots, and flowers with a concave thalamus, regular perianth of 4–6 coloured sepals, which are barely united at the base, imbricated in 2 circles in the bud, free from the 1-celled ovary containing 1 or 2 pendulous ovules, and mostly fewer than the stamens; anthers opening by 2 or 4 lid-like valves (fig. 428); fruit a berry or a drupe; seed without perisperm; radicle superior.

Illustrative Genera: *Cinnamomum*, Burm.; *Camphora*, Nees; *Nectandra*, Rottl.; *Sassafras*, Nees; *Tetranthera*, Jacq.; *Laurus*, Tournef.; *Cassytha*, L.

Affinities, &c.—The peculiar operculate dehiscence of the anthers distinguishes this Order from most of the allied Monochlamydeous groups: from Atherospermaceæ, which share this character, Lauraceæ are distinguished by their solitary carpel and pendulous ovules. The Lauraceæ have also affinities with Myristicaceæ in the qualities of their products; but the structure differs widely. *Cassytha* is a remarkable form, having a twining parasitic leafless stem like *Cuscuta*, bearing true Lauraceous flowers. The inner perianth is developed after the manner of a corolla simultaneously, the outer successively like a calyx (Payer). In some Laurels, e. g. *Oreodaphne*, the outer anthers are introrse, the inner ones extrorse. The fruit of some genera is curious, as that of *Dehaasia*, which is borne upon a thickened peduncle, somewhat like that of *Anacardium*. The pollen is generally spherical, without pores or bands. The solitary carpel is sometimes divided into several compartments by false partitions. The subdivisions of the Order depend on the habit, position of fruit, number of parts to the flower, unisexuality or polygamism, &c.

Distribution.—A large Order, principally found in cool situations in the tropics; one (*Laurus nobilis*) is a native of Europe, and a few of North America. Traces of them in a fossil condition are first met with in Eocene formations.

Qualities and Uses.—The most marked properties of these plants depend on the presence of aromatic oils and Camphor; but the bark of some has valuable tonic and febrifuge qualities, the timber of many kinds is valuable, and the Order affords a number of edible fruits. True Cinnamon is the bark of *Cinnamomum zeylanicum*; Cassia-bark is derived from *C. Cassia* and other species; many other trees of the Order are noted for the possession of an aromatic bark of similar character, and furnish false Cinnamons in South America and other countries. Camphor is produced in the wood, branches, and leaves of *Camphora officinarum*, and is obtained by dry distillation; some species of *Cinnamomum* contain a considerable quantity of this substance. The aromatic fruits of some of the Lauraceæ furnish false Nutmegs, the Clove-nutmegs of Madagascar being the seeds of *Agathophyllum aromaticum*, the Brazilian Nutmegs those of *Cryptocarya moschata*, &c. The bark of *Nectandra Rodiæi*, the Bibiri of Guiana (from which Warburg's Fever-drops are made), is said to be a valuable febrifuge; the bark of the root of *Sassafras officinale* is highly esteemed in North America for its diaphoretic powers; *Benzoin odoriferum* has similar properties, and the oil of its aromatic berries is stimulant. The fruit of *Persea gratissima* is the highly praised West-Indian Avocado Pear; it contains much fixed oil. The timber of *Nectandra Rodiæi* is the Green-heart wood of Guiana, remarkable for its hardness and solidity; *Persea indica* furnishes a kind of coarse mahogany in the Canaries. Camphor-wood is sometimes used by cabinet-makers on account of its odour. *Laurus nobilis*, the Bay-tree or classic or true Laurel, is a native of the South of Europe, and is hardy in the south of England; its aromatic leaves are used for flavouring confectionary. These must not be confounded with those of the Cherry-laurel, a *Prunus*, and not a

true laurel, and which contain much hydrocyanic acid. A concrete green oil, called Oil of Bays, is obtained from the true Laurel leaves.

The ATHEROSPERMACEÆ are trees like Monimiaceæ, but with the flowers sometimes perfect, the anthers opening by lid-like valves, and the perispermic seeds erect; the nuts are enclosed in the tube of the perianth, and the persistent styles grow out into feathery awns, whence the plants are called Plume-nutmegs. They are chiefly distinguished from Monimiaceæ by their anthers, which resemble those of Lauraceæ, from which they are distinguished by the apocarpous ovaries, the diclinous flowers, and erect perispermic seeds, and are allied to Myristicaceæ by the diclinous flowers and aromatic perispermic seeds. The valvate anthers here, as observed by Dr. Hooker, indicate affinity to Berberaceæ rather than to Lauraceæ.—Two of the genera, *Laurelia* and *Atherosperma*, are natives of Australia; *Doryphora* is Chilian; they have fragrant properties, and a decoction of the bark of *A. moschata* is sometimes used as a substitute for Tea.

MONIMIACEÆ are sometimes placed in this neighbourhood, but have been treated of formerly (see p. 200).

MYRISTICACEÆ (THE NUTMEG ORDER) are tropical trees with alternate, entire, leathery, exstipulate dotted leaves; flowers diclinous, apetalous, clustered or racemose; perianth 3- or rarely 4-fid, leathery, valvate; stamens of the barren flower distinct or monadelphous; anthers 3–12, perfect, extrorse; perianth of the fertile flower deciduous; carpels solitary or numerous, rarely 2, and distinct; ovules 1 in each cell; fruit succulent, containing a seed surrounded by a lobed arillus, and having a small embryo in copious oily-fleshy ruminated perisperm.—Illustrative Genera: *Myristica*, L.; *Hyalostemma*, Wall.; *Virola*, Aubl.

Affinities, &c.—The nearest relations of this Order are with the apocarpous Thalamifloral Orders, more particularly Anonaceæ, with which they agree in the dotted leaves, valvate æstivation, extrorse anthers, apocarpous ovaries and ruminated perisperm; but the flowers are usually perfect in that Order. The structure of the seeds connects Monimiaceæ and Atherospermaceæ with this Order; but they have opposite leaves, besides other peculiarities. The aril originates both from the hilum and the micropyle. In many points they resemble Magnoliaceæ, but differ in the valvate calyx, absence of corolla, monadelphous stamens, solitary carpel and ovule. The resemblance to Sterculiaceæ seems to have been overlooked; nevertheless there are many points of contact between the present family and the tribe Sterculieæ, in the apetalous unisexual flowers, the valvate calyx, the monadelphous stamens, the arillate seeds. In their active qualities and habit they somewhat resemble Lauraceæ.

Distribution.—Tropical India and America; most numerous in the former.

Qualities and Uses.—Aromatic and acrid. The common Nutmeg is the seed of *Myristica moschata* (Moluccas), Mace being the laciniated arillus surrounding this. Coarse, inferior Nutmegs are obtained from *M. Otoba* in Brazil, *M. spuria* in the Indian islands, and others of the

numerous American and East-Indian species. The bark and the rind of the fruit are acrid.

NEPENTHACEÆ are herbs or half-shrubby plants with alternate leaves which, when perfect, have a long stalk terminating in a pitcher with an articulated lid. Morphologically the pitcher is considered to be a dilatation of a gland at the top of the midrib of the young leaf. The flowers are diœcious, with a 4-merous perianth; stamens coherent in a solid column (as in *Cytisus*); anthers about 16, extrorse; ovary free, 4-angled, 4-celled; seeds very numerous, attached to the sides of the dissepiments. Embryo in fleshy perisperm.—The relations of this Order are at present obscure. Most authors connect them with Aristolochiaceæ.—They are natives of the tropical region of Asia, and one is found in Madagascar, another in the Seychelles. They are cultivated in our stoves on account of their curious and often beautiful pitchers. These latter entrap, dissolve, and digest insects and other animal matter, their glands containing a digestive ferment capable of acting in the presence of an acid.

GYROCARPEÆ are usually stationed in this vicinity, but have been already treated of under Combretaceæ, *ante* p. 262.

THYMELACEÆ. THE LACE-BARK ORDER.

Coh. Daphnales, *Benth. et Hook.*

Diagnosis.—Shrubs or trees with an acrid and very tough (not aromatic) bark, entire leaves, and perfect flowers, with a regular and simple, usually coloured perianth, bearing ordinarily twice as many stamens as its lobes, free from the 1-celled, 1-ovuled ovary; seed suspended; perisperm none or sparing; radicle superior.—Illustrative Genera: *Daphne*, L.; *Pimelea*, Banks & Sol.; *Lagetta*, Juss.; *Hernandia*, Plum.

Affinities, &c.—Among the Monochlamydeous Orders this may be distinguished from Santalaceæ by its free ovary; from Elæagnaceæ by its perfect or polygamous flowers and pendulous seed; from Lauraceæ by the longitudinal dehiscence of the anthers; from Proteaceæ by its pendulous seeds and imbricated perianth. The flowers are mostly perfect, but polygamous in the tribe *Hernandieæ*. The flower-tube is probably of receptacular origin. The liber is developed in numerous separable layers in the bark of these plants. The Order is divided into tribes according to the presence or absence of petaloid scales or glands. *Hernandieæ* are by some constituted as a distinct Order, differing from Thymelads in habit, structure of bark, position of styles, and 2-seriate perianth.

Distribution.—A rather large Order, most abundant at the Cape of Good Hope and in Australia, but found sparingly in all other parts of the world.

Qualities and Uses.—The bark is usually acrid, and that of Mezereon (*Daphne Mezereum*) and other plants is used as a local irritant; taken internally it is an irritant poison. *Daphne Laureola*, the Spurge Laurel, another native species, has similar qualities—as also *D. Gnidium* and *D. pontica*, favourite garden shrubs, and other species. The liber of *Lagetta lintearia* (West Indies) is separable into lace-like laminæ, whence it is

called the Lace-bark tree, and the liber of some *Daphnes* furnishes useful fibres, and in other cases is manufactured into paper. The berries of *Daphne* are poisonous; but the seeds of *Inocarpus edulis* are eaten roasted like chestnuts. *Daphne*, *Pimelea*, and some other genera include many handsome cultivated plants, the perianth being petaloid.

AQUILARIACEÆ are a small group of plants, of tropical Asia, included by some in Thymelaceæ, but having a 2-celled ovary, or, if 1-celled, then with 2–3 1-ovuled parietal placentas, and sometimes a 2-valved dehiscent capsule; one ovule is sometimes abortive; and the fruit in some cases is an indehiscent succulent berry.—The heart-wood of *Aquilaria ovata* and *A. Agallochum* is known as Eagle-wood or Aloes-wood, and contains a resinous matter of stimulant quality.—Genera: *Aquilaria*, Lam.; *Gyrinopsis*, Gærtn.

ELÆAGNACEÆ are shrubs or small trees with silvery-scurfy leaves and diœcious or polygamous flowers; perianth free from the ovary, its tube becoming hard or pulpy, and berry-like in the fruit; stamens as numerous as the lobes of the perianth, and alternate with them, or twice as many; ovary 1-celled, 1-seeded, seed ascending; embryo straight, with thin perisperm and an inferior radicle.—The species are generally diffused in the northern hemisphere, separated from the Thymelaceæ by the ordinarily diœcious structure and the ascending ovule; *Elæagnus*, which has perfect or polygamous flowers, forms the link. From Proteaceæ they are separated by the valvate calyx and the indehiscent fruit. The pollen is triangular or ovoid (Mohl). The scurfy scales upon the leaves are elegant microscopic objects.—The berries of *Hippophaë rhamnoides*, Sea Buckthorn, common on our sea-coast, are sometimes used in fish-sauces, but are said to have narcotic properties. Those of *Elæagnus orientalis* are eaten in Persia, and those of other species in India. The flowers of some species are very fragrant. Traces of plants of this Order have been seen in Miocene and more recent deposits.

PROTEACEÆ.

Coh. Laurales, *Benth. et Hook.*

Diagnosis.—Shrubs or small trees usually with umbellate branches; leaves hard, dry, opposite or alternate, exstipulate: flowers usually bisexual, apetalous: perianth 4-cleft, valvate: stamens 4, superposed to the segments, sometimes partially barren: anthers opening longitudinally; ovary single, simple, free, with 1 ovule, or 2 or more ovules in 2 rows, ascending or descending: seeds without perisperm; embryo straight; radicle generally inferior.—Illustrative Genera: *Protea*, L.; *Grevillea*, R. Br.; *Hakea*, Schrad.; *Banksia*, L. fil.

ıs, &c.—The Order is divided into two tribes according as the fruit is dehiscent or indehiscent. In *Bellendena* the stamens are free. In

Simsia and some other genera the anthers are syngenesious. The arrangement of the stigmas and stamens to favour cross fertilization is often very singular. The pollen-grains are usually triangular, sometimes elliptic. The development of the lobes of the perianth is successive, not simultaneous, hence the perianth may be considered as calycine. The remarkable habit of these plants is a striking characteristic; and, besides the rigid foliage, we have the valvate perianth with the stamens opposite the lobes, and the radicle pointing to the base of the ovary, to distinguish this Order from the Thymelaceæ and nearest Monochlamydeous Orders. The structure of the stomata of the coriaceous leaves is very curious, and presents many modifications.

Distribution.—A large Order, the species of which are found chiefly at the Cape and in Australia. Fossil Proteads have been found in Eocene beds, and these Dicotyledons are among the first of which traces remain to us.

Qualities and Uses.—The wood is perhaps the most valuable product of these plants, being largely used for firewood where they abound; sometimes it is used for joinery when hard wood is required. The striking character of their evergreen foliage, and the brilliant colours of the heads of flowers, render them great favourites in cultivation, and the genera above cited will be found in most large collections of greenhouse shrubs. *Macadamia ternifolia* furnishes an edible seed.

EUPHORBIACEÆ. The Spurge Order.

Coh. Euphorbiales, *Benth. et Hook.*

Diagnosis.—Herbs, shrubs, or trees, mostly with a milky acrid juice, and leaves usually alternate and stipulate; monœcious or diœcious flowers; perianth various or none; the fruit of 1–3 or several 1–2-seeded carpels, united round a central column, separating when ripe; embryo straight in perisperm.

Character.

Thalamus flat or concave, or prolonged. *Flowers* diclinous, axillary or terminal, sometimes enclosed in a cup-shaped involucre. *Calyx* inferior, with internal glandular or scaly appendages, sometimes wanting. *Corolla,* of petals or scales as many as the sepals, or wanting. *Stamens* definite or indefinite, distinct or monadelphous; *anthers* 2-celled, sometimes opening by pores. *Ovary* free, sessile or stalked, 1-, 2-, 3-, or many-celled; *styles* as many as the cells, distinct or combined, or wanting; *stigmas* combined or separate and bifid; *ovules* 1 or 2, suspended from the inner angle of each cell beneath a prominent "obturator" or placental outgrowth. *Fruit* dry, the carpels splitting and separating elastically from the axis, or succulent and indehi-

scent; *seeds* suspended, 1 or 2 in each cell, often with an arillus; *embryo* in fleshy perisperm; *radicle* superior.

This Order is divided by Müller into two main divisions, according to the size and breadth of the cotyledons, the number of the ovules, the æstivation of the calyx, &c. Baillon divides them according to the number of the ovules in the first instance, the presence or absence of perisperm, the presence of an "obturator" or process of the placenta, the sexual condition of the flowers, &c.

ILLUSTRATIVE GENERA.

Hura, *L.*	Jatropha, *Kth.*	Euphorbia, *L.*
Hippomane, *L.*	Ricinus, *Tournef*	Cluytia, *L.*
Cœlebogyne, *J. Sm.*	Rottlera, *Roxb.*	Xylophylla, *L.*
Mercurialis, *L.*	Croton, *L.*	Phyllanthus, *L.*
Acalypha, *L.*		

Affinities, &c.—As the more familiar forms of this Order are either apetalous, or even destitute of a calyx, it is usually arranged among the Monochlamydeæ in elementary works; but a large proportion of the exotic genera have the corolla represented either by scales or petals. The common Spurges (*Euphorbia*), the principal native representatives of the Order, have a very remarkable inflorescence, or "cyathium," by some considered as a simple flower; there is a cup-like involucre (calyx according to Baillon, who reverts to Linnæus's original idea), within which are formed a number of stamens with an articulation in the filament, together with a stalked tricarpellary ovary (fig. 429). Each one of the

Fig. 429.

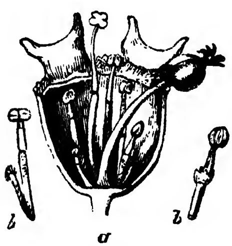


Fig. 430.

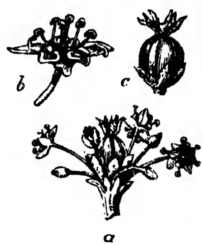


Fig. 429. *a*, Vertical section of the involucre of *Euphorbia Lathyris*, containing one stalked pistillate flower and six monandrous staminate flowers; *b*, *b*, staminate flowers of other species of *Euphorbia*, the left-hand without a perianth, the right with a small perianth at the base of the stamen.

Fig. 430. *Monotaxis tridentata*: *a*, involucre, with one pistillate and several staminate flowers; *b*, a separate staminate, *c*, a separate pistillate flower.

stamens, according to R. Brown and many others, represents a male flower reduced to its lowest term; for a minute bract exists at the base of each filament, and in some species a perianth occurs at the articulation, which is, in fact, the base of the flower; the ovary in like manner represents a female flower. This is well illustrated by the exotic genus *Mono-*

taxis (fig. 430), where the cup-like involucre is replaced by scales, and, instead of the jointed filaments, we find several stalked male flowers, with perianth and stamens, surrounding one female flower. Warming adopts Brown's view of the nature of the "cyathium," and further considers the stamens either as buds or as caulomes, each stamen representing a distinct flower, and each of the five bundles of stamens in *Euphorbia* being a sympode.

Three is the ordinary number of carpels; but *Mercurialis* has but two, and some exotic genera but one; on the other hand, 9 or even 15 (*Hura*) are occasionally present. The fruit is usually dry and dehiscent, but in *Sarcococca* succulent. *Ricinus* has much divided stamens. Considerable variety of habit occurs; some of the foreign *Euphorbiæ* have fleshy, spiny stems, somewhat resembling those of the Cactaceæ, *Xylophylla* and *Phyllanthus* having leaf-like flowering branches; and a number of large tropical trees belong to this Order.

These plants approach very closely to Malvaceæ and specially to Sterculiaceæ, the composition of the ovary being analogous, and the stamens often monadelphous; *Aleurites*, *Jatropha*, and other genera have a corolla much resembling Malvaceæ; and there is a further affinity to Rhamnaceæ. On the other hand, looking to their diclinous character and frequently incomplete flowers, they approach the Urticaceæ, from which they are, as a whole, distinguished by their compound ovaries: such genera as *Eremocarpus*, having but one carpel, connect the two groups. Some of the genera have stinging-hairs like Urticaceæ (*Jatropha*).

Distribution.—A very large Order, generally diffused over the globe; especially abundant in Equinoctial America. A few species are indigenous to this country.

Qualities and Uses.—These plants mostly produce a lactescent juice, which contains caoutchouc; the watery part of this sap is generally more or less acrid, purgative, emetic, or powerfully poisonous, from the presence of a principle dissipated by heat; starch abounds in the roots of some kinds, while oil of a purgative character is common in the seeds; the bark of some of the trees has tonic properties; the wood of several is very valuable for its hard close texture; and several of the plants furnish dyes. The lactescent juice of *Hevea* (*Siphonia*) *elastica* is the source of the "bottle" Caoutchouc of Brazil and Guiana, and various other species of *Hevea* also furnish it; *Aleurites lactifera* yields Gum-lac in Ceylon; *Euphorbia antiquorum* and *E. canariensis* are believed to yield the gum-resin called Euphorbium. The common Spurges (*Euphorbia*) have purgative properties; the root of *E. Ipecacuanha* is used as an emetic in North America; and the species of *Mercurialis* have similar properties, especially *M. perennis*, which is unsafe to use, since it produces violent purging, and even sometimes convulsions and death. The most deadly member of the Order seems to be the Manchineel (*Hippomane Mancinella*), a Panama plant, the juice of which is so acrid as to cause ulceration when dropped on the skin, and its apple-like fruit has a vesicating juice; the juice of *Excæcaria Agallochum* and of *Hura crepitans* has similar properties. The glandular hairs of *Mallotus philippinensis* furnish the drug known as Kamala, used for tape-worm and for dyeing purposes.

The oily seeds are mostly purgative: Croton oil is expressed from those of *Croton Tiglium* and *Pavana* (East Indies); Castor-oil from those of

Ricinus communis, in which the purgative property is found to reside in the embryo, not in the perisperm; the seeds of *Hura crepitans* and *Curcas* (*Jatropha*) *purgans*, the "Purging-nut," are violent cathartics, and those of *Euphorbia Lathyris* are sometimes employed in the same way. The solid oil obtained from the seeds of *Stillingia sebifera*, the Tallow-tree, is used for making candles in China. Cascarilla bark, with tonic properties, is obtained from *Croton Eleuteria* (Bahamas); *C. pseudo-quina* and other species have similar qualities. *Oldfieldia africana* is the African Teak-tree. *Crozophora tinctoria* furnishes the dye called Turnsole; *Rottlera tinctoria* (East Indies) a scarlet dye. The pure starch obtained by grating and washing the roots of *Jatropha Manihot* (*Manihot utilissima*) forms, under the name of Mandioc or Cassava, a most important article of food in South America; the finer particles of starch, softened by heat, and afterwards granulated, constitute Tapioca. The washing removes a narcotic poisonous matter which exists in the sap: the Indians dissipate this principle by heat, simply roasting the roots. It is a shrub about 8 feet high, with a large root, sometimes weighing 30 lbs., and is cultivated all over the tropics, but especially in America. Numerous Crotons are grown for their beautiful foliage.

Buxaceæ constitute a very small Order, formerly included among Euphorbiaceæ, but differing in the absence of milky juice, in the loculicidal capsules, ovules pendulous from the inner angle of the cells of the ovary, micropyle superior and internal. The leaves of the common Box (*Buxus*) are purgative; the wood is specially used for engraving and for turners' purposes.

Daphniphyllaceæ are constituted by Müller (of Argau) a distinct group, differing from the two preceding in their small embryo concealed in perisperm, and in the ventral raphe.

Scepaceæ are a small group of East-Indian plants, allied to Euphorbiaceæ, but having the flowers in catkins, thus forming a transition to the Cupuliferæ and Betulaceæ.—Genera: *Scepa*, Lindl.; *Lepidostachys*, Wall.

Penæaceæ are a small Order of Cape evergreen shrubs, related to Proteaceæ, but having a 4-celled ovary, 4 stigmas, and a 4-celled dehiscent or indehiscent capsule.—The drug called Sarcocol has been supposed to be derived from some of these plants; but this is doubtful. Genera: *Penæa*, L.; *Sarcocolla*, Kth.; *Geissoloma*, Lindl.

Lacistemaceæ are a small group of shrubs belonging to the woods of tropical America, with alternate, dotted, stipulate leaves, with apetalous, polygamous or diclinous flowers, and a 1-celled ovary with parietal placentas. Their position is doubtful; they have an amentaceous inflorescence, a perianth like that of Urticaceæ, filaments like those of Chloranthaceæ, and an ovary like that of Samydaceæ or Bixaceæ, with arillate seeds as in the latter Order.

Empetraceæ are low shrubby evergreens, with the foliage and aspect of Heaths: the flowers are small, diclinous; the perianth consists of 4–6 persistent hypogynous scales, the innermost sometimes petaloid; stamens

2-3, alternate with the inner scales; ovary free, on a disk 2-9-celled; ovules solitary; fruit fleshy, with 2-9 nuts; seeds 1 in each nut, ascending, perispermic; radicle inferior.—These plants have the appearance of Ericaceæ, the fruit even being like that of Vacciniæ, while the stigmas and the general structure of the flowers are Euphorbiaceous; but from the Euphorbiaceæ they differ in the ascending seed and inferior radicle.—They are mostly natives of Northern Europe and North America. Hooker places them near Olacaceæ. The leaves and fruit are slightly acid, agreeable; the berries of *Empetrum nigrum*, the Crowberry, are eaten; the Greenlanders prepare a fermented liquor from them. The Portuguese use the berries of a *Corema.*—Genus, *Empetrum.*

Batis maritima, a succulent shrub with opposite leaves, unisexual flowers arranged in catkins, is found in the salt marshes of the West Indies. The fruits are all fused in a mass with the bracts. It is sometimes made the type of an Order, but is regarded by Lindley as very close to Empetraceæ. Others place it near to Tamariscineæ or Chenopodiaceæ. It is sometimes used in West-India pickles.

URTICACEÆ. The Nettle Order.

Coh. Urticales, *Benth. et Hook.*

Diagnosis.—Herbs, shrubs, or trees with stipules and monœcious or diœcious or, rarely, polygamous flowers; perianth regular, free from the 1-celled (rarely 2-celled) ovary, or absent; stamens equal in number to the lobes of the perianth, and superposed to them, or sometimes fewer, uncoiling elastically; embryo straight in the perisperm when this is present, the radicle pointing upwards.

This Order is divided by Weddell into the following tribes:—1. Ureræ. Leaves with stinging-hairs; leaves opposite, or if alternate arranged spirally; perianth of female flower 4-parted, rarely tubular, always free. *Urtica*, L.—2. Procrideæ. Leaves without stinging-hairs; leaves opposite, or if alternate distichous; perianth of female flower free, 3-5-parted; stigma brush-like. *Pilea*, L.—3. Bœhmerieæ. Plants without stinging-hairs; leaves alternate or opposite; perianth of female flower free or adnate to the ovary, frequently tubular, rarely very short. *Bœhmeria*, L.—4. Parietarieæ. Plants without stinging-hairs; leaves alternate; flowers diœcious or polygamous; perianth of female flower tubular, free. Inflorescence bracteate. *Parietaria.*—5. Forsköhlieæ. Plants without hairs or with hardened hairs; leaves alternate or opposite; flowers diclinous, involucrate; perianth of female flower tubular or wanting. *Forsköhlia.*

Affinities, &c.—This Order is nearly related to the Malvaceæ, Tiliaceæ, and Euphorbiaceæ on the one hand, and to the amentiferous Orders on the other; differing from the former in the simple ovary, from the latter in the

usual presence of perisperm in the seeds, and in the flowers not being arranged in catkins. There is a further relation to the Chenopodiaceæ, which, however, besides the circumstance that they are only occasionally diclinous, have the embryo curved round the outside of the perisperm. The pollen is generally spherical. The leaves abound in clusters of crystals contained in large cells (cystoliths). The leaves of Nettles are often oblique, the smaller lobe of the base of the leaf being directed towards the branch from which it springs, contrary to what generally happens in oblique leaves.

Distribution.—The *Urticeæ* are generally diffused, but are much more abundant in the intertropical regions than elsewhere.

Qualities and Uses.—Edible fruits and valuable fibres are the principal products of this Order. *Bœhmeria* (*Urtica*) *nivea* furnishes the fibre for Chinese "Grass-cloth," Rhea or Ramee; *B. Puya* yields another valuable fibre; and the fibre of the Stinging-Nettle (*Urtica dioica*) was formerly used; *U. tenacissima* furnishes cordage in Sumatra. The juice of some Nettles is extremely irritant.

Fig. 431.

Seed of *Humulus* opened.

CANNABINACEÆ constitute a small group often included under Urticaceæ, but differing in their stamens not being elastic, their elongated, not rounded, anthers, and in their curved aperispermic embryo (fig. 431). By Baillon they are placed with the Elms.—*Cannabis sativa* furnishes the hemp of commerce, which consists of the woody fibres of the plant separated by maceration. *C. indica* yields a narcotic resinous product known as Indian hemp. *Humulus Lupulus*, the Hop, is well known for its aromatic bitter properties.

ARTOCARPACEÆ are trees or shrubs, or rarely herbs, with milky juice; alternate leaves, usually provided with convolute deciduous stipules; diclinous flowers, males in catkins, females in heads or flat receptacles; perianth 3–4-parted or none; stamens not elastic; ovary 1-celled; ovule solitary; perisperm fleshy or none; embryo straight or curved; radicle superior.

The Order is divided into two tribes:—1. ARTOCARPEÆ, with stamens inflexed in the bud, e. g. *Artocarpus*. 2. MOREÆ, with straight filaments, e. g. *Morus*, *Ficus*.

Affinities, &c.—The main difference between this group and the Urticaceæ lies in the milky juice and general habit. By Baillon it is classed under Ulmaceæ (see that family). The inflorescence and fruit of these plants are curious: in *Dorstenia* the flowers are embedded in the top of a tabular fleshy peduncle (fig. 148); in *Ficus* enclosed in an excavated fleshy peduncle (fig. 147); in *Morus* the female flowers are developed in a sort of capitulum, and subsequently coalesce into a compound fleshy fruit, resembling a blackberry (fig. 307), but each "pip" is formed from a distinct ovary; in *Artocarpus* the numerous flowers are crowded on a globular fleshy peduncle, which enlarges into a large fleshy fruit, sometimes weighing 30 lbs. *Ficus indica* (the Banyan tree) and some other

species of the same genus are remarkable for sending down numerous roots from their branches, which strike into the earth and convert the tree into a kind of grove.

Distribution.—The Artocarpaceæ constitute a large group, whose members are almost exclusively tropical and subtropical in both hemispheres.

Qualities and Uses.—Most of these plants have a milky juice, containing more or less of an acrid poisonous principle and of caoutchouc. *Broussonnetia papyrifera* is the Paper-Mulberry tree, the inner bark of which is used for making paper &c. in China and the South-Sea Islands. *Antiaris saccidora* has a fibrous bark, used for cordage and matting, also *Cecropia peltata*, *Brosimum*, &c. Caoutchouc is largely obtained from *Castilloa elastica*, *Ficus elastica*, and other species; a milky juice, of very nutritious character, containing nearly 4 per cent. of fibrin and albumen, is obtained from the Cow-tree of South America, *Brosimum* (*Piratinera*) *utile*. The renowned Upas-tree of Java is a large tree, *Antiaris toxicaria*, which has a very poisonous juice; and it is stated that linen made from its fibres, if badly prepared, produces great irritation of the skin. The fruit of *Maclura aurantiaca*, the Osage Orange, has an orange-coloured pulp, used by the North-American Indians to stain their skin; the wood of *M. tinctoria* is used by dyers under the name of Fustic. *Morus alba*, the White Mulberry, is largely cultivated in Italy and the East for feeding silkworms. *Morus nigra* yields the Mulberries of our gardens. *Artocarpus incisa* yields the Bread-fruit. *Dorstenia Contrayerva* was formerly esteemed as a tonic and diaphoretic. The wood of *Ficus Sycomorus*, the Sycamore-fig, is very durable, and is supposed to have been used for mummy-cases. The seeds of the plants of this Order are generally wholesome and nutritious.

Stilaginaceæ constitute an Order of trees or shrubs, with alternate, simple, leathery leaves and deciduous stipules; flowers diclinous, spiked, with a single 2-, 3-, or 5-parted perianth; stamens 2 or more on a tumid receptacle; anthers 2-lobed, dehiscing at the apex; ovary free, 1–2-celled, each cell with a pair of suspended ovules; seed perispermic; embryo straight; radicle superior.—These plants, natives of Madagascar and the East Indies, are nearly allied to *Urticeæ*, differing chiefly in the pulvinate disk, inelastic stamens, and anthers bursting at the apex. The drupaceous fruits of *Antidesma pubescens* and *Stilago Bunias* are subacid and agreeable.

Phytocrenaceæ are an Order with somewhat obscure relations, consisting of a few East-Indian climbing shrubs with a curiously organized wood. They have diclinous flowers; but the rudiments of the abortive sexual organs exist in the flowers of both kinds, and the flowers have both calyx and corolla. They are sometimes included among the *Artocarpeæ*, but have seeds with abundant perisperm. Bentham and Hooker place them with Olacaceæ, but the affinity seems remote.—**Genera:** *Phytocrene*, Wall.; *Iodes*, Blume, &c.

ULMACEÆ (THE ELM ORDER) consists of trees with watery juice, alternate stipulate leaves, perfect or monœciously polygamous flowers; perianth free, membranous, campanulate or irregular (fig. 432); stamens definite; filaments straight or moderately incurved in the bud; ovary free, 1–2-celled; styles or stigmas 2; fruit a single samara (fig. 433) or a drupe; seed suspended, with little or no perisperm; radicle superior.—Illustrative Genera: Tribe 1. CELTEÆ. Ovary 1-celled. *Celtis*, Tournef.; *Mertensia*, H. B. K.—Tribe 2. ULMEÆ. Ovary 2-celled. *Planera*, Gmel.; *Ulmus*, L.

Fig. 432.

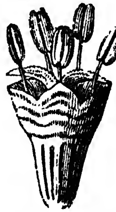


Fig. 433.

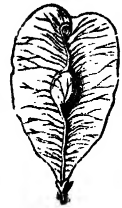


Fig. 432. Flower of *Ulmus*.
Fig. 433. Fruit of *Ulmus*.

Affinities, &c.—These plants, chiefly natives of northern countries, are very closely related to the Artocarpaceæ and Urticaceæ, and are scarcely distinguished by any general character except the polygamous structure of the flowers. The pollen is ellipsoid with five pores (Mohl). They are timber-trees with bitter astringent bark; *Ulmus campestris* is the common Elm-tree, *U. montana* the Scotch or Wych Elm. *Celtis australis*, called the Nettle-tree, has a drupaceous fruit of astringent quality.

PLATANACEÆ (THE PLANE ORDER) consists of trees with watery juice, alternate palmately lobed leaves, sheathing stipules, and monœcious flowers in separate and naked globular heads, destitute of calyx and corolla, or surrounded by scales or bristles; the fruits consisting of heads of clavate 1-seeded nucules furnished with a bristly down along the base; seeds solitary, rarely 2, pendulous; embryo in very thin perisperm; radicle inferior.—The Plane-trees (*Platanus*, L.), natives of North America and the Levant, naturalized in our parks and squares, are chiefly remarkable for the beauty of their form and foliage. The stipules are intra-axillary and sheathing, the petioles dilated at the base and concealing the bud, owing to the fusion of the edges over the bud. The structure of the inflorescence is amentaceous as regards arrangement and the absence of envelopes; but the ovaries are like those of *Artocarpeæ*, from which they are divided chiefly by the achlamydeous flowers, the inferior radicle, and the presence of perisperm in the seed.

MYRICACEÆ constitute a small Order of shrubs with resinous-dotted, often fragrant leaves; monœcious or diœcious achlamydeous flowers, both kinds in short scaly catkins; stamens 2–16; ovary 1-celled, with 1 erect ovule; fruit drupaceous; embryo without perisperm; radicle superior. They differ from the other amentiferous Orders in the simple and free ovary; they are also related to Urticaceæ, but differ in the amentaceous inflorescence and in the structure of the seed. They have many points in common with Juglandaceæ, but differ in their achlamydeous flowers and superior ovary.—They are aromatic shrubs or trees, with tonic and astringent properties; and wax, resin, and oil are obtained from them. *Myrica Gale*, the Bog-Myrtle or Dutch Myrtle, yields an aromatic oil and secretes wax; *E. cerifera*, the Wax-Myrtle, secretes a green wax;

Comptonia asplenifolia is used in cases of diarrhœa in North America. The fruit of *Myrica sapida* is eaten in Nepal.—Genera: *Myrica, Comptonia.*

BETULACEÆ (THE BIRCH ORDER) consists of trees or shrubs; monœcious, with both kinds of flowers in scaly catkins, achlamydeous, 2 or 3 under each bract (scales of the flowers whorled in *Alnus*); ovary 2-celled, 2-ovuled, ripening into a dry, 1-celled, 1-seeded, often winged nut, without a cupule; seed pendulous, aperispermic; radicle superior. Illustrative Genera: *Betula*, L.; *Alnus*, L.

Affinities, &c.—This small Order is distinguished from Cupuliferæ and Juglandaceæ by the free ovary, and the regular occurrence of 2 carpels in the ovary, one cell, however, being usually obliterated in the fruit. From

Fig. 434.

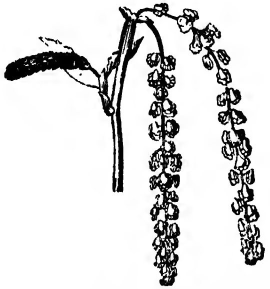


Fig. 435.

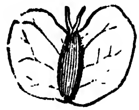


Fig. 434. Male and female catkins of the Birch.
Fig. 435. Samaroid fruit of the Birch (*Betula alba*).

Salicaceæ they differ in the 2 cells, and by the solitary ovule in each cell. These plants belong chiefly to temperate and cold climates; *Betula nana* and *Alnus incana* form dwarf shrubs further north than any other woody plants, except some Willows. The bark is regarded as tonic and astringent, and an empyreumatic oil is obtained from that of the common Birches *Betula alba* and *glutinosa*, which gives the peculiar odour to Russia leather. The bark of *B. papyracea* is used for making baskets and many other articles in North America. The sap of *B. alba, nigra,* and *lenta* yields sugar at certain seasons. *Alnus glutinosa* is the common Alder; its wood is esteemed for work to remain under water, and for the manufacture of charcoal; the leaves and female catkins are sometimes used by dyers.

SALICACEÆ (THE WILLOW ORDER) consists of diœcious trees or shrubs, with both kinds of flowers in catkins, one flower under each bract, entirely destitute of envelopes, or with a membranous cup-like perianth (fig. 437, *Populus*); the fruit a 1-celled and 2-valved pod, containing numerous seeds clothed with long silky down; no perisperm; radicle inferior.—Illustrative Genera: *Salix*, L.; *Populus*, L.

, &c.—This amentiferous Order, consisting of but two genera,

one of which, *Salix*, is rich in species, is at once distinguishable by the 2-valved fruit having numerous seeds clothed with silky hairs. The 2-carpellary ovary and the inflorescence connect them closest with Betulaceæ. By some they are placed near Tamariscaceæ.—The Willows (*Salix*) and Poplars (*Populus*) belong to temperate and cold climates. Some are valuable for their timber; the young shoots of Willows furnish material for basket-work; and the bark has usually febrifuge properties, depending on the presence of Salicine. *Populus nigra* is the common

Fig. 436.

Fig. 437.

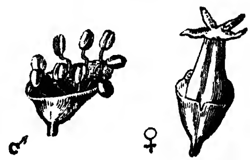


Fig. 436. ♂ catkin of Willow.
Fig. 437. ♂ male and ♀ female flower of *Populus*.

Black Poplar, of which the Lombardy Poplar appears to be a fastigiate variety; *P. tremula* is the Aspen; *P. alba* is the Abele, or White Poplar. *Salix babylonica* is the Weeping Willow; Sallows and Osiers are the shoots from pollard stumps of *Salix viminalis, vitellina*, &c.; *Salix alba* is the ordinary Willow-tree found by river-sides. Willow-wood is used to some extent in turning, on account of its white colour, and it is esteemed for making charcoal.

CASUARINACEÆ are pseudo-leafless trees with pendulous, jointed, striated branches, the nodes sometimes with short toothed sheaths (whorls of leaves); flowers in spikes, diclinous; the barren flowers in loose spikes, with 2 bracts and 1 or 2 sepals, the latter adhering at their points; stamen 1; anther 2-celled; the fertile flowers in dense spikes or heads, with 2–4 bracts; ovary 1-celled, with 1–2 ascending ovules; fruit a collection of follicles aggregated with the bract into cones; seeds aperispermic, with a superior radicle.—The species form a small group consisting of trees of remarkable aspect, the branches having much the appearance of the branched *Equiseta*. The jointed stems and abortive leaves connect them also with *Ephedra* among the Gymnosperms, to which they approach also in the very reduced character of the flowers. The bracts or perianth-

segments are variable in number. The single stamen is central, and is considered to be a prolongation of the central axis. The ovary is, in some cases, spuriously 2-celled. They acquire large dimensions; and the wood of their trunks becomes very solid and heavy. The greater portion of them are natives of Australia, where they are called Beef-wood trees, from the red colour of the timber.

CHLORANTHACEÆ constitute a small Order, having the following characteristics. Herbs or under shrubs with jointed stems swollen at the nodes, opposite simple leaves with sheathing stalks and minute interpetiolar stipules; flowers in terminal spikes, achlamydeous, hermaphrodite or sometimes diclinous, with a scaly bract; stamen 1, or, if more, coherent and definite; in the hermaphrodite flower anthers 3, 2 lateral 1-celled, median 2-celled; ovary 1-celled, 1-seeded; seed pendulous; embryo in the apex of fleshy perisperm; radicle inferior; cotyledons divaricate.—Nearly related in general character to Piperaceæ, but differing from them and from Saururaceæ in the absence of the double endosperm, the embryo being without the "amniotic sac;" there is a more distant relationship to Urticaceæ, and perhaps some affinity to Loranthaceæ.—The plants are tropical, commonly have fragrant properties; and the roots of *Chloranthus officinalis* and *brachystachys* are esteemed as tonic, febrifuge medicines in the West Indies. The species of *Hedyosmum* have similar properties. The leaves of *Chloranthus inconspicuus* are occasionally used to flavour Tea.

PIPERACEÆ. THE PEPPER ORDER.

Coh. Piperales, *Benth. et Hook.*

Diagnosis.—Shrubs or herbs with jointed stems, opposite, whorled, or, by suppression, alternate leaves; stipules absent, in pairs, or singly opposed to the alternate leaves; flowers spiked, hermaphrodite or diœcious, achlamydeous, in the axil of a bract, with which they are sometimes confluent; stamens 2 or more; anthers 1–2-celled; ovary free, simple, 1-celled, with a single erect orthotropous ovule; fruit somewhat fleshy; seed erect, with the embryo in a distinct sac (*amnios*) at the top of copious perisperm; radicle superior.—Illustrative Genera: *Peperomia*, R. & P.; *Macropiper*, Miq.; *Chavica*, Miq.; *Cubeba*, Miq.; *Piper*, L.; *Artanthe*, Miq.

Fig. 438.

Section of seed of *Piper*.

Affinities, &c.—The stems of some of the Piperaceæ present so irregular a form of arrangement of the wood, that some authors have regarded them as belonging to the Monocotyledonous class; but this structure is not exactly that of the Monocotyledons, and they have a dicotyledonous embryo and reticulate-veined articulated leaves; they may, however, be regarded as connecting the two classes through Araceæ, themselves somewhat anomalous forms of Monocotyledons. The chief peculiarity of

the wood is the presence of woody bundles (sometimes forming a complete ring) in the pith. The tribe *Peperomieæ* are said by C. de Candolle to have no cambium ring. The *Piperæ* always have a cambium ring. Their nearest relations are Chloranthaceæ and Saururaceæ; but they differ from the former in the sac of the embryo, the erect seed, and the alternate leaves; from the latter in the simple ovary and the absence of stipules. They are more distantly related to Urticaceæ.

Distribution.—A large Order, the species of which are for the most part tropical; most abundant in the hottest parts of America and of the East-Indian islands, in damp situations.

Qualities and Uses.—Pungent and aromatic, more or less astringent or narcotic. Black Pepper consists of the dried fruits of *Piper nigrum*; White Pepper is the same with the fleshy epicarp removed by washing. Long Pepper consists of the dried spikes of *Chavica Roxburghii* (*Piper longum*); other species of *Chavica* are used in India and Tropical America, with *Artanthe adunca*, &c. The leaves of *Chavica Betle* are chewed, mixed with slices of the Betel Nut (*Areca oleracea*) and lime, by the Malays and other Indian races. The ripe fruits of *Cubeba officinalis*, *canina*, *Wallichii*, &c. form Cubebs, or Cubebs Pepper, and have aromatic, stimulant, and purgative properties; *Artanthe elongata* and *adunca* are said to have similar virtues. *Macropiper methysticum*, the Ava or Kava of the South-Sea Islands, has powerful narcotic properties. The leaves, or powdered leaves of *Artanthe elongata* are also esteemed as a styptic, known by the name of Matico, in South America (other plants are also called by this name, such as *Eupatorium glutinosum*). Most of the plants of this Order possess some of the above properties, more or less powerfully marked; *Artanthe crocata* yields a yellow dye, obtained from the spikes of fruit.

SAURURACEÆ constitute a small group of aquatic or marsh plants of North America, China, and North India, related to Piperaceæ, but differing in the compound ovaries and stipulate leaves and wood destitute of bundles in the pith. They are more or less acrid. *Saururus cernuus* is sometimes used in medicine, an irritating cataplasm being made from the root.

CERATOPHYLLACEÆ are aquatic herbs with whorled, finely dissected leaves, and minute axillary and sessile monœcious flowers, without floral envelopes, but with an 8–12-cleft involucre in place of a calyx; the fertile flower is merely a simple 1-celled ovary, with a suspended orthotropous ovule; the seed filled by a highly developed embryo with 2 cotyledons and a conspicuous plumule; radicle very short, inferior.—The genus *Ceratophyllum*, of which some authors describe 6 species, while others reduce them to 1, constitutes this Order, consisting of aquatic plants with whorls of leaves, and having almost the appearance of some Confervoids. The relations of *Ceratophyllum* are obscure: it has been connected with the Haloragaceæ from its resemblance to *Myriophyllum*, while Lindley places it provisionally among his Urticales, and Baillon refers it to Piperaceæ. The most remarkable point is the structure of the seed, which is aperispermic, and consists principally of 2 fleshy cotyledons, inside which stand a decussating pair of leaves, and within these, surrounded by withered endo-

sperm-cells, is the plumule, bearing the whorl of leaves separated by a short internode from the second pair. In the highly developed state of the plumule they resemble *Nelumbium.* They are found in ditches, &c. throughout the northern hemisphere, and they have no active properties.

CALLITRICHACEÆ are small aquatic annuals, with opposite entire leaves, and solitary polygamous axillary flowers, without any proper floral envelopes; stamens 1 or 2; fruit 4-lobed, 4-celled, 4-seeded; seeds pendulous; embryo inverted in the axis of fleshy perisperm; radicle very long, superior.—This Order consists of the genus *Callitriche*, comprehending the Starworts of our freshwater pools, of which 6 species occur in Europe and North America. Their flowers are so simple that it is difficult to settle their affinities. Some regard them as related to *Hippuris*, among the Haloragaceæ; but they appear to be truly achlamydeous, whence others consider them allied to Euphorbiaceæ, from which they differ only in their 4-lobed ovary and in the structure of the seed. They have no known properties.

PODOSTEMACEÆ are aquatics, growing on stones in fresh running water, with much the aspect of Seaweeds or Mosses; the minute flowers bursting from a spathe-like involucre; perianth 0 or of 3 sepals; stamens 1 or many, hypogynous; ovary free, compound, 2–3-celled, with 2 3 stigmas; ovules numerous; fruit a many-seeded, ribbed capsule, the placentation of which is axile or parietal; seeds aperispermic, with a straight embryo.—This is a group of very curious plants, having a distinctly Dicotyledonous embryo, but much the habit of the Monocotyledonous Naiadaceæ. Lindley regards them as related to Elatinaceæ, or possibly to Plantaginaceæ, by way of *Littorella*. *Hydrostachys* is diclinous, the other genera perfect. In some of the genera there is no real distinction between stem and leaf, the structure being analogous to a thallus. They are most numerous in South America; some occur in India; one in North America. They have no active properties; but some species of *Lacis* are used for food on the Rio Negro and other parts of South America.

Series 2. INFERÆ or EPIGYNÆ.

Ovary inferior. Perianth more or less distinct in the male or female flowers, or both, sometimes none or very indistinct.

JUGLANDACEÆ. THE WALNUT ORDER.

Coh. Quernales, *Hook.*

Diagnosis.—Trees with alternate pinnate leaves, without stipules: the sterile flowers in catkins, with a simple scale or an irregular perianth; the fertile solitary, or in small clusters, with a regular 3–5-lobed perianth adhering to the incompletely 2–4-celled ovary, with only 1 erect ovule. Fruit consisting of a dehiscent husk enclosing a woody shell, containing a large 2–4-lobed orthotropous, aperispermic seed; cotyledons oily,

sinuous; radicle short, superior.—Illustrative Genera: *Juglans*, L.; *Carya*, Nutt.

Affinities, &c.—A small but well-marked group, nearly related to Cupuliferæ, but differing in the solitary ovule and in the absence of a cupule. From the resinous juices and pinnate leaves, they have been regarded as allied to Terebinthaceæ; but the latter have petals, a free ovary, and curved ovule. The Walnut (*Juglans regia*) is a well-known example of the Order. The wood of this, as well as of *J. nigra*, is valued by carpenters. The nuts of *J. cinerea* are called Butter-nuts in Canada. *Carya alba*, the Hickory of North America, has tough, elastic wood and an edible nut, as also has *C. oliviformis*.

CUPULIFERÆ. THE OAK ORDER.

Coh. Quernales, *Hook.*

Diagnosis.—Trees or shrubs with alternate simple feather-veined leaves and deciduous stipules; monœcious flowers, the barren in catkins or clustered, the fertile solitary or clustered and furnished with an involucre which forms a cup or covering to the flowers (fig. 439); ♂ stamens 5–20, inserted at the base of scales or of a membranous perianth; ♀ ovary crowned by the rudimentary teeth of an adherent calyx, 3- or more celled

Fig. 439.

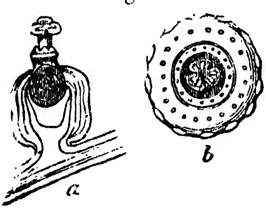


Fig. 440.

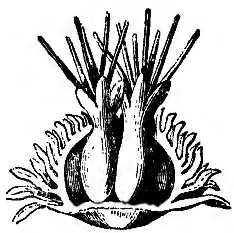


Fig. 439. *Quercus*: *a*, vertical section of female flower; *b*, cross section.
Fig. 440. Opened involucre with two flowers of *Castanea*.

(fig. 440); stigmas nearly sessile; ovules solitary, or 2 in a cell; fruit a nut, 1-celled by abortion, woody or leathery, more or less enveloped by the involucre (cupule), containing 1 or 2 seeds (the rest being abortive), destitute of perisperm; cotyledons large and fleshy; radicle minute, superior.

ILLUSTRATIVE GENERA.

Tribe 1. EU-CUPULIFERÆ. *Male flowers with a perianth, female perianth 6-lobed; ovary 2–6-celled; fruit of 1–3-seeded nuts, in a hard or thick cupule or involucre.* Quercus, *L.*; Castanea, *Gærtn.*; Fagus, *L.*

Tribe 2. CORYLACEÆ. *Male flowers with a single scale, female perianth irregularly lobed; ovary 1-celled with 2 pendulous ovules; fruit a nut in a foliaceous involucre.* Carpinus, *L.*; Corylus, *L.*

Affinities, &c.—Related to the Urticaceæ, but differing in the inferior, many-celled ovary, and in the character of the fruits and seeds. From Betulaceæ and Salicaceæ, to which they are closely allied, they are separated by the inferior position of the ovary. Brongniart indicates an affinity with Pomaceæ. Some authors separate the Corylaceæ from Cupuliferæ by reason of the achlamydeous male flowers and of the leafy cupule of the female flowers of the former. In the Hazel (*Corylus*) at the time of flowering the female flower consists of ovary begirt with an adherent and scarcely perceptible calyx, and surmounted by two styles. The cells of the ovary with their ovules do not appear for months afterwards. The pollen is generally roundish or ovoid, with three plaits. The cupule of the Oak seems to be the dilated concave end of a branch; the scales represent stipules. The maturation of the acorns takes place in one year, or not until the second year after formation. The rind of an acorn, chestnut, or beech-nut, and the shell of a filbert, are the hardened and consolidated calyx-tube and ovary enclosing the (by abortion) solitary seed.

Distribution.—A large group, the members of which are for the most part natives of forests of temperate climates.

Qualities and Uses.—Timber-trees of great importance, some also having edible fruits; the bark and other parts more or less astringent. *Quercus*, a very extensive genus, includes *Q. Robur*, British Oak, of which there are two varieties, *Q. sessiliflora*, Durmast, and *Q. pedunculata*. *Q. Suber* furnishes cork, which is a thickening of the cellular layers of the outer bark, which increase year by year, and are separated by deep-coloured periderm-cells. The outer rough cork is called the male cork; the inner cork-cells near the liber are much finer and constitute what is called the female cork. The cork is removed about once in seven years. *Q. Ægilops* has large rough cupules, extensively used by dyers under the name of Valonia; *Q. coccifera* is the Kermes Oak; *Q. tinctoria* furnishes Quercitron Bark; Nut-galls are produced by the attacks of an insect on *Q. infectoria*; *Q. Ilex* is the Holm Oak, or Evergreen Oak of our shrubberies. Between 200 and 300 species of *Quercus* exist, some of which have edible fruits. The leaves of *Q. mannifera* exude a sugary substance; *Corylus avellana* is the Filbert or Hazel; *Castanea vesca* the Sweet Chestnut; *C. americana* produces a smaller nut; *Fagus sylvatica*, the common Beech, has a valuable hard wood, as also *Carpinus Betulus*, the Hornbeam; and *Ostrya virginica* is called Iron-wood in North America. Oil is obtained by pressure from the seeds of the Beech and the Hazel; the Nut-oil of the latter is largely used by painters.

Garryaceæ.—A small Order of shrubs of North-west America, and having amentaceous inflorescence, unisexual flowers, a 2–4-parted perianth, definite stamens, and a 1–3-celled inferior ovary, with 2 pendulous ovules; seeds with a minute embryo in abundant perisperm. They differ from Hamamelidaceæ in their apetalous flowers, definite stamens, and baccate fruit. By Bentham and Hooker they are included under Cornaceæ. They are also allied to *Gunnera* in Araliaceæ.

LORANTHACEÆ. The Mistletoe Order.

Coh. Santalales, *Benth. et Hook.*

Diagnosis.—Shrubby plants with leathery greenish foliage, parasitic (naturally grafted) on trees; leaves opposite, exstipulate; flowers perfect or diclinous; perianth adherent, with 4–8 lobes; stamens 4–8, superposed to the segments of the perianth; ovary inferior, 1-celled, with 3 ovules pendulous from a free central placenta, or 1, erect, arising from the base of the cell; fruit succulent; seed 1; embryo in fleshy perisperm; radicle remote from the hilum.—Illustrative Genera: *Viscum*, Tournef.; *Loranthus*, L.; *Myzodendron*, Sol.

Affinities, &c.—These remarkable plants are distinguished by their peculiar parasitic habit. They are nearly allied to Santalaceæ, presenting, like that Order, a naked nucleus as the representative of the ovule, and are further characterized by the strange extrusion of the apex of the embryo-sac before or after fertilization. Besides the curious structure of the flowers, they have an anomalous organization of the wood, which has no medullary sheath of spiral vessels, but contains scalariform tubes. The germination of the seeds exhibits some interesting phenomena: in *Viscum* the seeds adhere to the young shoots of trees by means of the viscid pulp of the fruit; in *Myzodendron* there are long feathered processes, which coil round the branches on which they settle; in either case the seeds are retained in contact with the surface of the shoot upon which they rest, where they germinate, and push their radicle through the bark down to the cambium-layer, with which they contract an organic adhesion and become grafted, just as a bud does in the ordinary gardening operation of budding Roses, &c. According to Van Tieghem the stamen and the sepal, and the carpel and the ovule each correspond to a single leaf, the one organ being a deduplication from the other. The male flower consists of four leaves in decussate pairs, each polleniferous upon the upper face. In the female flower the ovule is reduced to an embryo-sac, which is a cell of the parenchyma of the base of the third pair of bracts or carpels. The embryo of *Viscum* does not appear for several weeks after the application of the pollen. Two or more embryos occur sometimes in one seed and become united together. In *Loranthus* no trace even of ovule is observable till after fecundation. *Nuytsia* has four cotyledons, or perhaps two deeply divided.

Distribution.—A large Order, of which some are European, as *Viscum album* and *Loranthus europæus*; the majority belong to the hotter parts of Asia and America; *Myzodendron* belongs to the temperate parts of the southern hemisphere.

Qualities and Uses.—Some of the plants have astringent properties; but the most important product perhaps is the viscid pulp of the fruit of *Viscum album*, which is used for making bird-lime. The curiosity attaching to the parasitic habit is the most striking feature in this Order, most of the plants growing like our common Mistletoe, *Viscum album*; this appears capable of grafting itself on a wide variety of trees, being most common on the Apple-tree with us, but occurring on Thorns, Willows, Limes, Oaks, Elms, and even on Fir-trees.

SANTALACEÆ (THE SANDAL-WOOD ORDER) consists of herbs, shrubs, or trees with entire leaves; the 4–5-cleft perianth valvate in the bud, its tube adherent to the ovary. Stamens superposed to the lobes of the perianth; ovary 1-celled, with 2–4 ovules suspended from the apex of a free stalk-like central placenta, arising from the base of the cell; the indehiscent fruit 1-seeded; seed with abundant perisperm filling the pericarp; embryo straight; radicle superior.—Illustrative Genera: *Thesium*, L.; *Osyris*, L.; *Santalum*, L.

Affinities, &c.—The definite pendulous ovules, consisting of a naked nucleus attached to a free central placenta and protruding the embryo-sac before or after fertilization, are very remarkable and striking characters in this Order. The entire seed is formed in the embryo-sac, outside the nucleus. Van Tieghem thinks that the stamen is not autonomous, but is a production from the sepal. He also thinks that the placenta is a duplication from the ovary, and that the ovule is the termination of one of these appendages, one for each of the three carpels. Baillon considers that the perianth of *Thesium* and *Santalum* is a corolla by reason of the simultaneous, not successive, evolution, &c. The "calycode" is an expansion of the receptacle. The nearest relations are probably with the Loranthaceæ, which, however, differ in habit, being stem-parasites, and having less complete and sometimes imperfect flowers. *Thesium* is partially parasitic on the roots of other plants. There is a more remote relation to Olacaceæ and allied Orders in the perianth and ovule.

Distribution.—A small Order: the European and North-American species are inconspicuous herbs; in India and Australia they are shrubs or small trees.

Qualities and Uses.—Sandal-wood, the wood of *Santalum album*, is perhaps the best-known production of this Order. The seeds of the Quandang Nut (*Fusanus acuminatus*) are eaten like almonds in Australia. Some species are astringent.

BALANOPHORACEÆ are root-parasites with amorphous fungoid stems, destitute of leaves, never green, with fleshy subterraneous rhizomes or tubers, and naked or scaly peduncles bearing spikes of flowers; flowers mostly unisexual; male flowers conspicuous, with a tubular entire, slit, or 3–5-lobed perianth, valvate in the bud; stamens usually 3–5, more or less connate, or distinct; female flowers very minute; perianth with the tube adherent, and mostly without a limb, or 2-lipped; ovary inferior, mostly 1-celled; styles 2; ovule solitary, pendulous; fruit a small, compressed, 1-seeded nut; seed with hard granular perisperm and a lateral amorphous embryo.—Illustrative Genera: *Balanophora*, Forst.; *Cynomorium*, Michel.; *Sarcophyte*, Sparrm.; *Helosis*, Rich.

Affinities, &c.—The peculiar parasitic habit and fungoid texture of the plants of this and the two succeeding Orders have induced many authors to separate them from all other Flowering plants as a distinct class; but the grounds of this separation seem untenable: parasitism occurs in plants of the most varied structure, and this character of habit is not even of ordinal value. The structure of the stems of Balanophoraceæ is merely a

degraded form of the Dicotyledonous type; and the flowers are in like manner provided with all the real essentials of the Phanerogamous structure, since the acotyledonous embryos, upon which stress has been laid, occur in Orobanchaceæ, Orchidaceæ, and various other Orders. The vascular tissue of the parasite is continuous with that of the host-plant. Stomata and hairs are alike scarce in these plants. Hooker, who has elaborately investigated this Order, regards them as having affinity, in their floral structures, to the Haloragaceæ, where, as in *Hippuris*, we find in plants not parasitic a reduction of the parts of the flowers as complete as that in *Cynomorium*. They are closely related to *Gunnera*; but differ in their parasitic habit, absence of leaves, &c. The ovule of these plants is generally reduced to a unicellular nucleus, and that nucleus destitute of coats.—They occur on the roots of various Dicotyledonous trees, chiefly on the mountains of tropical countries, especially the Andes and the Himalayas; a few occur at the Cape and other parts of Africa, and some in Australia. *Cynomorium* is found at Malta, North Africa, the Levant, and the Canary Islands.

Qualities and Uses.—Many of the plants seem to have styptic qualities; *Cynomorium coccineum* was formerly highly valued by surgeons for this purpose, under the name of *Fungus melitensis*. Its radicle is directed upwards in germination (Weddell). Some have a very disagreeable odour, others are eaten like Mushrooms.

CYTINACEÆ are root-parasites of fungoid texture, with flowers perfect or monœcious, solitary and sessile or clustered at the end of a scaly stem; perianth tubular at the base, 3-6-parted above, andrœcium columnar, connected by four septa with the base of the perianth; anthers in heads, each surmounted by a subulate connective and opening by slits; ovary inferior, surmounted by a style which has four lobes at the base superposed to the perianth segments; ovules very numerous, growing over 8 branching parietal placentas, generally with only one coat; fruit a 1-celled, many-seeded berry; seeds imbedded in pulp, perispermic or aperispermic; embryo amorphous.—*Cytinus hypocistis* (South Europe) is parasitic upon the roots of *Cistus*, and has unisexual flowers; *Hydnora*, a Cape plant, growing upon fleshy *Euphorbiæ* and other succulent plants, has hermaphrodite flowers. Except in habit, they have very little connexion with the Balanophoraceæ; and from Rafflesiaceæ they differ in the 3-merous structure of the perianth and the longitudinal dehiscence of the anthers. In *Hydnora* the ovule is immersed in the structure of the placenta, as the buds of some species of *Ornithogalum* in the leaf. These plants are supposed by some writers to have a connexion with the Monocotyledons through Bromeliaceæ.—*Cytinus* has astringent qualities; *Hydnora africana*, which has a putrid smell, is roasted and eaten by the African natives, and is also used for tanning purposes.—Genera: *Cytinus*, *Hydnora*.

RAFFLESIACEÆ are parasites of fungoid structure, without stems or leaves; the flowers solitary, sessile upon the branches of trees, surrounded by scales, perfect or diœcious; perianth 5–10-parted, with a circle of scales or a ring in the throat; anthers 2-celled, and opening by

distinct pores, upon a salver-shaped or subglobose column adhering to the perianth, numerous, distinct or connate, or concentrically many-celled with a common pore; ovules very numerous, growing all over the parietal placentas of the 1-celled ovary; fruit an indehiscent pericarp, with a great number of perispermic or aperispermic seeds with an undivided embryo.—Illustrative Genera: *Rafflesia*, R. Br.; *Sapria*, Griff.; *Pilostyles*, Guill.

Some of the Rafflesiaceæ occur parasitic upon species of *Cissus* in the East Indies, others on Leguminous plants in South America. They differ from Cytinaceæ in the absence of a stem, the 5-merous perianth, and the porous anthers. They are sometimes regarded as related to the Aristolochiaceæ. *Rafflesia Arnoldi*, a plant of Sumatra, is a wonderful object, consisting of a gigantic flower of fungoid texture, measuring 3 feet across, and weighing 14 lbs., emitting in decay a smell like putrescent flesh. This and other species seem to have styptic and astringent properties.

ARISTOLOCHIACEÆ. THE BIRTH-WORT ORDER.

Diagnosis.—Climbing shrubs or low herbs, with perfect, regular or irregular flowers; the conspicuous single tubular perianth (figs. 441, 442) (valvate in the bud) adherent below to the 6-celled ovary, which becomes a many-seeded 6-celled capsule or berry; stamens 6–12, more or less adherent to the style (fig. 443); anthers adnate, extrorse; ovules numerous; seeds perispermic; embryo minute—Illustrative Genera: *Asarum*, Tournef.; *Aristolochia*, Tournef.

Fig. 441. Fig. 442. Fig. 443.

Fig. 441. Flower of *Aristolochia Clematitis*.
Fig. 442. Perianth of *Asarum*.
Fig. 443. Ovary and stamens of *Aristolochia*.

Affinities, &c.—The apparent stipules of this order are the first leaves of an undeveloped bud. The six carpels are superposed to the stamens, and it has been said that the styles are only outgrowths from the back of the stamens. The ternary structure of the flowers of this Order, together with an aberrant structure of the wood, which presents no concentric rings, seems to indicate that these plants have affinities to such Monocotyledonous Orders as Dioscoreaceæ, Aroideæ, and Taccaceæ, although they are really Dicotyledonous. Their more immediate relationships are obscure; most authors connect them nearly with Nepenthaceæ, the affinities of which, again, are not clearly made out. They have many characters in common with Santalaceæ. Their stamens, adherent to the style, distinguish them from all other Monochlamydeous Orders.

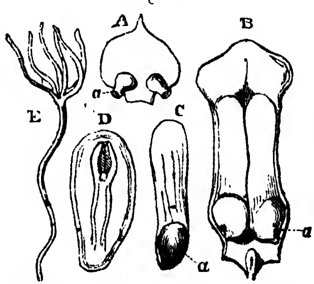
Distribution.—A large Order, the species of which are generally diffused; most numerous in tropical South America.

Qualities and Uses.—Some of these plants have enjoyed considerable reputation, having pungent, aromatic, and stimulant qualities. The *Aristolochiæ* take their name from the roots of *A. Clematitis*, *longa*, *rotunda*, and others being used as emmenagogues. *A. Serpentaria*, Virginian Snake-root, is one of the many so-called specifics for Snake-bites, and it is stomachic and tonic. It is worth notice that several species of *Aristolochia* in different countries are considered by the natives valuable remedies in cases of snake-bite. *Asarum europæum*, Asarabacca, is acrid; its leaves were formerly much used in a snuff employed in affections of the eyes. Some of these plants are very handsome climbers, with large cordate leaves and striking helmet-shaped flowers; those of *Aristolochia cordata* are large enough to be used as caps by the Indian boys in the Brazilian woods. The West-African *A. Goldieana* is equally large.

SUBCLASS II. *GYMNOSPERMIA.*

Phanerogamous plants, with achlamydeous unisexual flowers arranged in spikes, the male flowers consisting of antheriferous scales serially continuous with the leaves and collected in deciduous catkins. Pollen-grains dividing, prior to the emission of the pollen-tube, into secondary cells. The female flower consists either of open carpels (fig. 444, A), bearing naked ovules, standing in the axil of a bract, and arranged in persistent cones, or of naked terminal ovules surrounded by a few scales; seeds perispermic. The endosperm in the embryo-sac is formed previous to fertilization, and produces corpuscula or archegonia. Embryo bearing 2 cotyledons, which are simple or divided into several lobes—a whorl of 4 or more cotyledons (fig. 444, E) according to some authors.

Fig. 444.



A, carpel of *Pinus* (*a*, ovules); B, scale of cone (ripe carpel) of *Pinus*, with seeds (*a*) *in situ*; C, winged ripe seed (*a*, seed); D, section of seed, showing embryo in endosperm; E, embryo germinating.

The members of this group are remarkable as forming a bond of union,

in many important parts of their organization, between the Angiospermous Phanerogams and the higher Cryptogams; and this applies in some degree to their histological as well as to their morphological construction. The Cycadaceæ have the habit of Palms, or of arborescent Ferns; their fertile foliar organs, or stamens and carpels, resemble in *Cycas* the fertile leaves of Ferns; in *Zamia*, as in Pinaceæ, the carpels approach nearer to the condition of the carpels of Angiosperms, but are flat or open.

The structure of the female flower has been a subject of much controversy among botanists; the account above given is that which is on the whole the most generally adopted, though it should be stated that many botanists regard the outer investment of the ovule as an ovary (Strasburger, Baillon, Sperk), in which latter case the scale supporting it would have more of the nature of a branch than of a foliar organ. The reasons for considering the reproductive bodies as naked ovules and not ovaries are thus summed up by Alph. de Candolle:—i. The mode of development is centrifugal as in ovules, not centripetal as in [most] ovaries; ii. The seeds of some Conifers (*Podocarpus*) are anatropal, a position unknown in ovaries; iii. The insertion is that of an ovule and not of an ovary. To this it may be added that the structure and arrangement of the tissues in the scale supporting the ovules are more akin to those of a leaf than to those of a branch. Anatomical investigation shows that while in Cycads the ovules are borne on the sides of a scale originating directly from the axis, in Conifers the ovuligerous scale is the production of an abortive secondary branch originating in the axil of a primary scale.

The arguments in favour of the Angiospermous character of Conifers and their allies are thus summed up by Strasburger:—i. The female flowers of *Coniferæ* and *Gnetaceæ* are metamorphosed buds. ii. Each flower consists of an ovary, destitute of any distinct perianth. iii. The single envelope of the flower of *Coniferæ* is homologous with the outermost of the three surrounding the ovule in *Gnetaceæ*, which latter, being homologous with the carpels of Angiosperms generally, must itself be considered as an ovary. iv. This ovary contains a single ovule, which is naked (consisting of the nucleus only) in all *Coniferæ*, whilst in *Gnetaceæ* it is protected by two coats. v. The integuments in *Gnetaceæ* are homologous with the ovular integuments in the higher Phanerogams. vi. These envelopes must be looked upon as foliar productions, both in *Coniferæ* and *Gnetaceæ*. vii. The nucleus of the ovule is formed by the extremity of the floral axis. viii. In both *Coniferæ* and *Gnetaceæ* the ovary is formed by two carpellary leaves, which are primitively distinct, but by the subsequent growth of their basal portion they form a tubular structure below; in some rare cases, however, they seem from the first to be completely united. ix. The ovular coats of the *Gnetaceæ* are, without exception, equally developed all round the ovules; each of them corresponds to a single leaf. x. Any foliar formation, such as makes its appearance in many *Coniferæ* between preexisting leaves (as, for instance, the fructiferous scale in *Abietineæ* or the cupule in *Taxaceæ*), is a disk or outgrowth of the axis; there are no such organs in *Gnetaceæ*. Professor Strasburger considers the term Gymnosperms to be inappropriate; but as *Taxads, Cycads, Conifers,* and *Gnetads* differ from other Phanerogams in having "corpuscles" instead of germinal vesicles, the terms *Archisperms* and *Metasperms* as substitutes

for those of Gymnosperms and Angiosperms respectively have been proposed. The embryo-sac, corresponding to the macrospore of higher Cryptogams, becomes filled with cellular tissue forming an endosperm, which is absorbed after a time in the cases where the seed takes two years to ripen, and is re-formed the following spring. The formation of the archegonia or corpuscula will be subsequently alluded to. After fertilization the corpusculum develops into a pro-embryo, from the extremity of which the embryo proceeds. Pinaceæ and Taxaceæ agree with Dicotyledons in habit; but the foliage of the latter approaches that of Ferns, while there are relations between their inflorescence and that of the Lycopodiaceæ; Gnetaceæ approximate to Casuarinaceæ and Chloranthaceæ in habit; and perhaps *Ephedra* may be compared with *Equisetum*. The pollen corresponds to the microspores of *Selaginella*, the division of its cells corresponding to the male prothallus of those plants.

PINACEÆ or CONIFERÆ. The Pine Order.

Order Coniferæ, *Benth. et Hook.*

Diagnosis.—Trees or shrubs, of exogenous structure (see *post*), mostly with evergreen, linear, needle-like or lanceolate leaves, sometimes tufted, sometimes imbricated, monœcious or diœcious; the female flowers in cones, consisting of imbricated scales or open carpels arising from the axils of bracts, and bearing (figs. 444 A & 445) 2 or more ovules on the upper face; fruit a woody cone (fig. 309, p. 152) or a succulent berry formed by coherence of a few fleshy scales (*galbulus*).

Illustrative Genera.

Suborder 1. Abietineæ. *Ovules inverted, with the micropyle next the base of the carpel; pollen oval.*

Pinus, *L.*
Abies, *Tournef.*
Araucaria, *Juss.*

Subord. 2. Cupressineæ. *Ovules erect, with micropyle superior; pollen spheroidal.*

Juniperus, *L.*
Thuja, *Tournef.*
Cryptomeria, *Don.*
Cupressus, *Tournef.*
Taxodium, *L. C. Rich.*

Affinities, &c.—The above diagnosis gives the essential character of this Order, which, however, deserves a little detailed notice, on account of the modifications occurring in the different genera, as well as on account of the difficulties which the structure of the inflorescence may present to the student.

Among the *Abietineæ*, in the common Scotch Fir (*Pinus sylvestris*) the male inflorescence appears in the form of a compound spike, each branch of which consists of a number of anthers arranged in a catkin; each anther is represented simply by a scale, arranged like the leaves, having 2 parallel pollen-cells, one upon each side of a connective which is produced into a little tongue beyond the pollen-cells (fig. 447), and resembling the scales of *Equisetum*. By A. Braun the entire male inflorescence was con-

sidered as a single flower. The nature of the pollen is further explained in the physiological part of this work. The female inflorescence consists of a cone, composed of single carpellary scales, each seated in the axil of a membranous bract, the whole spirally arranged round the axis; each carpel possessing, on the upper face at the base, 2 naked ovules, with their points directed towards the base of the carpel. In other *Abietineæ* the stamens are more complex: in *Cunninghamia* the anther is 3-celled; in *Araucaria* many-celled, the loculi consisting of free tubular bodies attached by their apices to a thickened connective at the upper end of a slender filament. The condition of the carpels also varies, *Araucaria* and *Dammara*

Fig. 445.

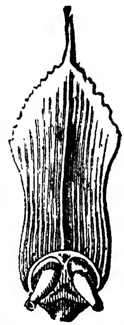


Fig. 446.

Fig. 447.

Fig. 445. Open carpel of *Pinus*, with two naked ovules at the base.
Fig. 446. Winged seed of Pine.
Fig. 447. Anther-bearing scale of *Pinus*.

having but 1 ovule, *Cunninghamia* 3, and other genera more. A diversity also appears in the cones, from the different ways in which the carpels are developed; in *Pinus sylvestris*, and many others, the upper ends become thickened into woody heads (*apophyses*) meeting in a valvate manner, forming the "tesselloe" of the continuous surface of the unopened cone, while in *Abies*, *Cunninghamia*, &c. the upper ends of the ripe carpels overlap in an imbricated manner. The bracts are obviously serially continuous with the leaves of the branch, but the scales within the bracts have been the subject of much controversy. The generally adopted view is that they represent two leaves fused together and produced from a contracted or undeveloped branch axillary to the bracts. Brongniart considered the scale as produced by an enation or chorisis from the bract. According to him, in the cones of *Cupressineæ* there are bracts and no scales; in those of *Abietineæ* the bracts are split to the base so as to form a bract and a scale superposed to it; while in *Araucaria* the cone consists of bracts only partially split.

In *Cupressineæ*, the stamens of *Cupressus*, *Juniperus*, *Thuja*, &c. are peltate, with several loculi under the overhanging connective; and the carpels representing the female flowers have in *Thuja* 2 ovules, in *Cupressus* many, in *Juniperus* 2 or only 1 erect ovule at the base; in *Juniperus* the carpels ripen into fleshy structures, cohering together so as

to form a kind of berry; in *Callitris* the cone is of globose form, and composed of 4 peltate scales, the *apophyses* of which meet in a valvate manner; the same is the case with a greater number of valves in *Cupressus*, while *Thuja* has the scales more distinctly imbricated, but still with thickened apophyses, which meet in a valvate manner (like those of *Pinus sylvestris*).

The curious fasciculate arrangements of the leaves of *Pinus*, where 2, 3, 4, or more occur together, with a common membranous sheath at the base, offer valuable distinctive characters for the species. It is probable that these so-called leaves are more properly to be considered as shoots, as in *Sciadopitys*. Their anatomical structure has lately formed the subject of examination by Bertrand, McNab, and others.

The affinities of the Pinaceæ are with Dicotyledons by their habit of growth, although there is an essential difference in the internal structure of their organs; the inflorescence of this and of the associated Orders is perhaps more highly organized than that of the Cycads, and is connected with Phanerogams, on the one hand, by the presence of distinct stamens and carpels, the latter producing a perfect seed; while the nature of the processes taking place in the development of the embryo (described in the Physiological Part of this work) indicates a close approach to the conditions which are met with in the higher Cryptogams, especially *Selaginella*. The leaves usually persist often for years. In *Thuja*, *Taxodium distichum*, and some others, the extremities of the branches fall with the leaves.

Distribution.—A considerable Order even in point of numbers, its representatives are met with in all parts of the world; the species of *Pinus*, *Abies*, and *Taxodium* growing socially, form characteristic forests in the northern hemisphere. They are represented in Palæozoic as well as in all the more recent formations.

Qualities and Uses.—Most valuable as timber-trees and as sources of important resins (turpentine, pitch, &c.) used in the arts, and aromatic oils and balsams having medicinal properties.

Pinus includes:—*P. sylvestris*, the Scotch Fir (North Europe); *P. Pinaster*, the Cluster-pine, a less hardy tree; *P. palustris*, the Swamp-pine of Virginia; *P. Tæda*, the Frankincense-pine. *Pinus Fremontiana*, *P. Lambertiana*, *P. Strobus*, &c. are other very valuable timber-trees, attaining a height of upwards of 200 feet. *Pinus Pinea*, the Stone-pine of the south of Europe, has edible seeds. *Abies* includes:—the Norway Spruce, *A. excelsa*; the Silver-Fir, *A. pectinata*; *Abies balsamea*, Balsam-of-Gilead Fir, and *A. canadensis*, Hemlock Spruce, both North-American. *Cedrus*, a subgenus of *Abies*, includes the Cedar of Lebanon (*Abies Cedrus* or *C. Libani*), and the Deodar (*C. Deodara*), which is supposed to be merely a variety of the last named. *Larix*, another subgenus, includes the European (*Abies Larix* or *Larix europæa*) and other Larches, characterized by deciduous foliage; *Araucaria* includes the enormous Chilian Pine (*A. imbricata*) and the Moreton-Bay Pine (*A. Bidwillii*). *Eutassa excelsa* is the celebrated Norfolk-Island Pine. *Dammara australis* is the Cowrie Pine of New Zealand; *D. orientalis* the Dammar Pine of India. *Sequoia* (or *Wellingtonia*) *gigantea* is a Californian Pine, attaining a height of 360 feet; *Microcachrys tetragona* is the Huon Pine of Tasmania.

Juniperus is best known in this country by the common Juniper shrub, *J. vulgaris*, or by the cultivated Savine, *J. Sabina*; but the species of other countries are more important, as *J. bermudiana* and *J. virginiana*, the "Red Cedars," the aromatic wood of which is used for cabinet-making and for blacklead pencils; *J. Oxycedrus*, a Mediterranean species, forms also good and durable wood. *Thuja occidentalis* and *orientalis* are the Arbor-vitæ trees of our shrubberies; *Cryptomeria* is now introduced also from Japan; *Cupressus sempervirens* is the common Cypress; *Callitris quadrivalvis*, the Arar-tree of North Africa, has odoriferous and durable wood; *C. australis* is the Oyster-Bay Pine of Australia. *Taxodium distichum* is the Deciduous Cypress of the United States, and characterizes the Cypress-swamps of the Southern States.

Among the above, turpentine, resin, and pitch are derived from many; important kinds of resin are:—common turpentine, resin, pitch, and Burgundy pitch, from *Pinus sylvestris*; Venice turpentine from the Larch; Strasburg turpentine from *Abies pectinata*; Bordeaux turpentine from *P. Pinaster* &c.; Canada Balsam from *Abies balsamea* and *A. canadensis*; Sandarac from *Callitris quadrivalvis*; Gum-Dammar from *Dammara australis*, &c. The berries of *Juniperus vulgaris* are aromatic, and are used for flavouring gin; they are diuretic; *J. Sabina* has still more active diuretic properties; and *Cupressus* and *Thuja* appear to have poisonous qualities. The large seeds of many other Pines, besides the Stone-pine, are eaten locally, in a fresh state, as of *Araucaria imbricata, A. Bidwilli*, &c. The bark of the Larch has been used to check profuse expectoration and internal hæmorrhage.

TAXACEÆ. The Yew Order.

Class Coniferæ, *Endl.* *Class* Gymnogens, *Lindl.*

Diagnosis.—Trees or shrubs with narrow rigid leaves or broad leaves (phyllodes, leaf-like shoots?) with forked nerves, unisexual naked flowers, surrounded by imbricated bracts, the male several together, each composed of one or several coherent anthers, the female of a solitary naked ovule, terminal or in the axil of a bract; the seed usually surrounded by a succulent coat.—Illustrative Genera: *Taxus*, L.; *Podocarpus*, L'Hér.; *Dacrydium*, Sol.; *Phyllocladus*, L. C. Rich; *Cephalotaxus*, Zucc.; *Salisburia*, Sm.

Affinities, &c.—The relations of this group, sometimes regarded as a Suborder of the Pinaceæ, are the same as those of that order; and from it these plants differ chiefly in the solitary ovule that replaces the cone. It must be admitted, however, that these plants with their solitary terminal ovule (*Taxus, Torreya*) favour the notion that the outer covering of the nucleus is ovarian not ovular, for there is nothing like an open carpel, and the two lips of the outer envelope decussate with the two upper leaves of the branch, which seems to indicate their ovarian origin. The leaves of *Salisburia*, and in a less degree those of other genera, are very similar to those of Ferns; and the stamens of *Taxus* closely resemble the sporanges of *Equisetum*. The cotyledons of *Salisburia* are fleshy, and in germinating do not escape from the seed. *Torreya* has ruminate perisperm.

Distribution.—A small group, the members of which inhabit temperate regions generally, or mountains in the tropics.

Qualities and Uses.—Agreeing in general with Pinaceæ; *Podocarpus*, *Dacrydium*, *Taxus* (Yew), &c. yield valuable timber. The leaves of the Yew are poisonous; but the pulp of the berries does not appear to share this property. The fruits of *Salisburia adiantifolia* are resinous and astringent.

GNETACEÆ are small trees or shrubs, usually with jointed stems, opposite, simple net- or parallel-ribbed, or minute and scale-like leaves, and unisexual (rarely hermaphrodite) flowers in catkins or heads; anthers 2–3-celled, opening by pores; female flower naked, or with two more or less combined scales, surrounding 1 or 2 naked ovules (?); seed succulent; embryo with two cotyledons, in the axis of fleshy perisperm.—Illustrative Genera: *Ephreda*, L.; *Gnetum*, *L.*; *Welwitschia*, Hook. f.

Affinities, &c.—This Order is chiefly interesting as furnishing a link to connect the Conifers with the Dicotyledons, if the plants be considered to have a truly Gymnospermous organization of the flower (a view strongly contested by Strasburger and others), while in general structure *Ephedra* approaches to *Casuarina*, and *Gnetum* to *Chloranthus*. They are destitute of the resin so characteristic of Conifers. The ovule presents the curious peculiarity that a third integument, immediately investing the nucleus, grows out into a long process like a style, and which projects from the foramen of the outer coat. *Welwitschia mirabilis* (fig. 448), a native of desert regions in South-western Tropical Africa, where it was discovered by the botanist whose name it bears, is, in many respects, the most interesting flowering plant now in existence. It consists of a woody trunk, about 2 feet high, with a long woody root, and terminating above in an irregularly lobed saddle-like mass, 4–5 feet in diameter. From a groove beneath the edge of this is given off, on each side, a broad leathery leaf, some 6 feet long, and split into numerous thongs. These leaves are supposed to be the persistent cotyledons; and no others are produced, though the plant attains an age of at least a hundred years, and probably more. The disk at the top of the stem is marked by concentric lines. The inflorescence consists of cones borne on forked branches which originate from the edge of the disk (fig. 449). The cones contain, some female flowers, others male flowers; the latter with an abortive ovule occupying the extremity of the axis (fig. 450). The male flower consists of a perianth, as in the male flowers of *Ephedra*, enclosing six stamens, united by their filaments into a short tube, and bearing globose anthers, which open by a 3-rayed chink. In the centre of the flower is a body like an ovary, with a terminal style-like prolongation and an expanded stigma. This pistil-like structure invests the nucleus of the ovule, which, in this case, is destitute of embryo-sac and embryo. The ovary-like body in this flower is shown, from its mode of development and structure, to be homologous with the coat of an ovule, and not to possess the characteristics of an ovary, except so far as superficial resemblance is concerned. The long styliform process is similar to that which occurs in the ovule of *Ephedra*. The ovule, then, of *Welwitschia*, according to Hooker, is strictly Gymnospermous, like those of Coniferæ. Strasburger and McNab, however, dissent from this view.

The male flower, according to these observers, consists of a dimerous perianth in two rows, six stamens (or two thrice-branched, lateral stamens), and

Fig. 448.

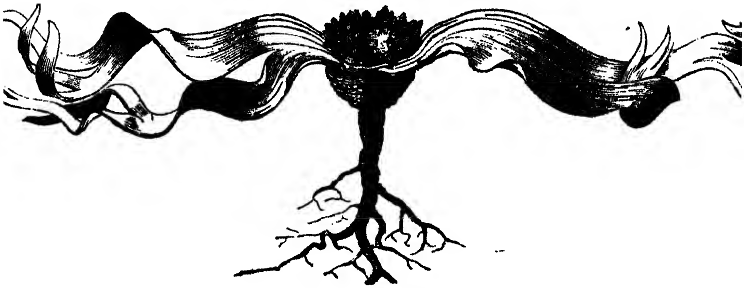


Fig. 449.

Fig. 450.

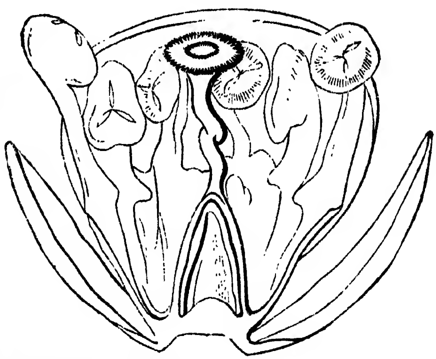


Fig. 448. *Welwitschia mirabilis*, greatly reduced.
Fig. 449. Portion of inflorescence of *Welwitschia*, reduced.
Fig. 450. Male or hermaphrodite flower of *Welwitschia*, reduced.

two carpels (antero-posterior), thus:—$P\,2+2\ A\,3+3\ \bar{G}\,2$. In the female flower there is neither perianth nor andrœcium, but two collateral carpels. The carpels in the so-called male flowers are antero-posterior, :; in the female collateral ·· . The ovule in the male flower is destitute of an integument, while in the female flower it is present in the shape of a single ring-like or tubular investment. The structure of the stem belongs to the Dicotyledonous type, but having, in addition to the other bundles, scattered vessels passing through the parenchyma, as in Monocotyledonous stems. Among the ordinary parenchymatous cells occur " spicular " cells of large size and irregular branching form; these are covered on the outside with rhomboidal crystals of carbonate of lime. Similar cells occur in the leaves of *Araucaria* among Pinaceæ.

Distribution.—*Ephedra* occurs in Europe, Asia, and South America, in temperate regions; *Gnetum* in tropical India and in Guiana.

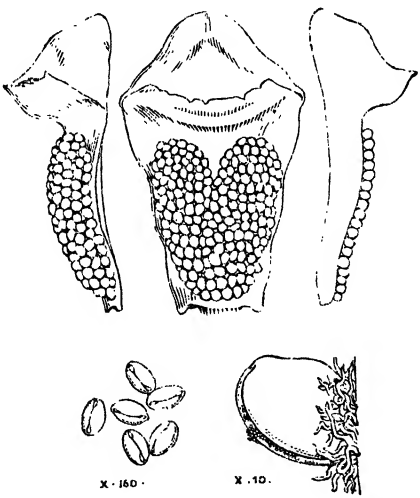
Qualities and Uses.—Unimportant; the branches and flowers of some *Ephedræ* were formerly used as a styptic drug.

CYCADACEÆ.

Subclass Gymnospermeæ, *Benth. et Hook.*

Diagnosis.—Palm-like, dwarf trees with simple trunks, having the internodes undeveloped, the surface tessellated with the scars of the fallen leaves; leaves clustered at the summit, pinnate (bipinnate in *Bowenia*), parallel-ribbed, more or less hard and woody, vernation straight, that of the lateral pinnæ circinate or flat, and imbricated: diœcious, the flowers in cones; the one-celled anthers covering the under surface of the male cone-scales (fig. 451);

Fig. 451.



Anther-bearing scales (nat. size), anther and pollen (magnified), of *Encephalartos.*

female flowers either peltate scales with ovules beneath, or flat scales with ovules at the base, or somewhat leaf-like scales with the ovules on the margins; seeds with a hard or succulent coat, con-

taining one embryo or several, in fleshy or mealy perisperm.—Illustrative Genera: *Cycas*, L.; *Dion*, Lindl.; *Zamia*, L.; *Encephalartos*, Lehm.; *Macrozamia*, Miq.; *Stangeria*, Moore.

Affinities, &c.—With the habit and appearance of Palms, and in some cases of Ferns (especially in the genus *Stangeria*), these plants agree with *Pinaceæ* in the essential peculiarities of the organization of their flowers and seeds, while the distribution of the reproductive organs over the leaf-like carpels and the antheriferous scales in *Cycas*, together with the occasionally circinate vernation of the leaf-segments, connect this Order with the Ferns, thus strengthening the relation between the Gymnosperms and the higher Cryptogams, which is so evident in the affinities between Pinaceæ and Lycopodiaceæ. The relationship to the higher Cryptogams is further indicated by the multicellular pollen of Cycads, which is analogous to the microsporangia of Rhizocarps.

Some difference exists in the condition of the reproductive organs. The flower-cones, composed of imbricated scales, appear to be axillary productions in *Zamia*; but in *Cycas* they are formed from the terminal bud, which subsequently grows on (as in the Pine-apple), so that here the terminal inflorescence does not arrest the growth of the axis: the formation of cones occurs at intervals; and when the scales fall off, after the pollen or the seeds are mature, the stem is found marked alternately with bands of scars of two kinds, those of the true leaves and those of the floral leaves (carpels and stamens). In *Zamia* the cones are lateral, like the spadices of many Palms. In *Cycas* the female cones are formed of large flat leafy carpels, with ovules arranged at some distance apart on the margins; the male cones are likewise formed of leafy scales, bearing numerous anthers (or loculi) scattered over the lower surface, the loculi being commonly grouped in fours like the sporanges of *Mertensia*. In *Zamia* the cones more nearly resemble those of Pinaceæ: the male cones are formed of peltate scales (with an apophysis as in the ripe cones of *Cupressus*), with the pollen-cases under the overhanging head; the female cones are composed of somewhat peltate scales bearing only a pair of ovules at the base. The pollen-sacs are numerous, sessile, or stalked, on the under surface of the thick persistent staminal scales. The pollen-cells are at first simple and more or less spherical, but subsequently they divide into two or more cells of different sizes, the pollen-tube ultimately protruding from the larger cell. The compound pollen, forming a sort of male prothallium, is similar to that of Pinaceæ.

L. C. Richard regarded the female flower of Cycads as formed of a gamosepalous calyx adherent to a half-inferior ovary. Payer thought the ovary was achlamydeous, surmounted by a short style. Alexander Braun also considered the tegument of the ovule to be ovarian. Van Tieghem, basing his opinion on the arrangement of the vascular bundles, thinks the Cycads are truly Gymnospermous, the ovules being borne on the edges of a flat leaf. Gris also arrived at the conclusion that the outer covering of the ovule was of the nature of an ovular coat, its filiform prolongation being the micropyle, not a style. In the ovule of *Cycas*, as of *Ricinus*, the attached portion of the nucleus, where the coat is still confluent with it, is covered with a network of vessels proceeding from the single bundle which passes, under the name of raphe, through the coat of the ovule.

It is noteworthy that the fruit or seed may be perfect in all its parts without fecundation having taken place, the embryo alone not being formed. Thus in hothouses one often sees the female plants ripening their fruit; but although even the perisperm of the seed is fully formed, there is no embryo, the male plant being not in cultivation or not in flower at the time. In the ripe seed the archegonia or corpuscula are very large, as also are the suspensors or proembryos, of which usually only one develops a perfect embryo, the others remain as withered threads.

Distribution.—Tropical and temperate parts of Asia, America, Africa, and Australia. In a fossil state they appear first in the Carboniferous strata, and are abundant in the Lias, Wealden, and Lower Cretaceous formations.

Qualities and Uses.—The chief economic value of these plants consists in the possession of a kind of farina like Sago, consisting of the starch washed from the internal parenchyma of the trunk, or obtained from the mealy perisperm of the seeds. *Cycas revoluta* and *C. circinalis* are "Sago" plants in Japan and the Moluccas. Various species of *Encephalartos* form what is called "Caffer-bread" at the Cape; *Dion edule* (seeds) furnishes a kind of Arrowroot in Mexico.

Class II. MONOCOTYLEDONES.

Angiospermous Phanerogams, with stems in which the woody bundles are isolated and diffused through a parenchyma in which there is no distinction of pith and bark, the individual woody bundles rarely being developed further after the fall of the leaves to which they belong; the leaves (very commonly sheathing at the

Fig. 452.

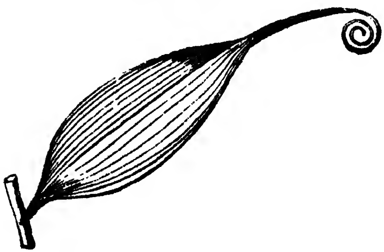


Fig. 455.

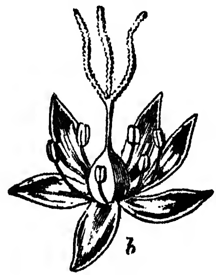


Fig. 453.

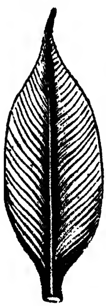


Fig. 454.

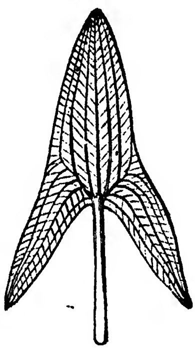


Fig. 456.

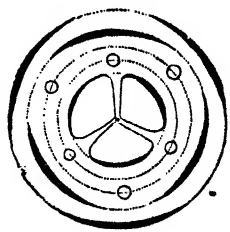


Fig. 457.

Fig. 452. Leaf of *Gloriosa*.
Fig. 453. Leaf of *Canna*.
Fig. 454. Leaf of *Sagittaria*.
Fig. 455. Ternary flower of *Luzula*.
Fig. 456. Diagram of ditto.
Fig. 457. Monocotyledonous embryo of *Potamogeton*.

base) generally with a number of nearly parallel, straight or curved ribs (fig. 452), or with similar ribs given off from a midrib (fig. 453); the cross veins suddenly smaller (fig. 454), occasionally

netted-veined: the flowers generally with three organs in each whorl (fig. 456); the floral envelopes often all petaloid, or all green or scale-like, rarely with a green calyx and coloured corolla; seed with an embryo with one cotyledon only.

The floral formula is, as a rule, P 3+3 A 3+3 G 3, subject to many modifications by suppression, adhesion, &c.

Division I. **Petaloideæ.**

Monocotyledons, with the floral envelopes consisting of a regular or irregular perianth, of two whorls, both petaloid, or more rarely both herbaceous, sometimes with a green or scaly calyx and a petaloid corolla (rarely, as in *Naiadeæ*, with a scaly uniform perianth, or quite achlamydeous): the flowers mostly perfect, more rarely unisexual; the leaves with the primary ribs parallel, or with a midrib and parallel secondary ribs, or rarely reticulated somewhat in the same manner as Dicotyledons, but with the veins branching at more obtuse angles.

Exceptions, &c.—The greater part of the Orders here associated have a natural connexion in the structure of the perianth (either superior or inferior), the syncarpous ovaries, and the perispermic seeds. But a small assemblage of Orders which are included here diverge greatly from the general character, while they differ so much from each other that they cannot very well be separated in the form of one distinct group: these are the Hydrocharidaceæ, the Alismaceæ, and the Naiadaceæ, which agree in the common character of an aperispermic seed: but the first have an inferior compound ovary, and seem to approach Bromeliaceæ; the second have more or less distinct carpels, together with a green calyx and coloured corolla, such as occurs in Commelynaceæ; while the third, with uniform scaly perianth or achlamydeous, also apocarpous, in their simpler forms approach in habit to the Araceæ.

Series 1. EPIGYNÆ.

Flower-tube not separate (adherent to) from the ovary.

Exceptions, &c.—Many Bromeliaceæ have free ovaries.

TACCACEÆ are tropical perennial herbaceous plants with tuberous roots and large leaves, somewhat resembling Araceæ in habit, but with epigynous, petaloid, hermaphrodite flowers, the perianth of which is tubular; concealing 6 stamens with petaloid filaments incurved and hooded at the apex; ovary 1-celled, with 3 parietal placentas projecting more or less into the interior; fruit a berry; seeds with fleshy perisperm.—The plants are commonly regarded as connecting the epigynous Monocotyledons with the Aristolochiaceæ, a Dicotyledonous Order with 3-merous flowers; they have affinity in habit to the Araceæ, and in the flowers approach Bromeliaceæ. The watery juices of these plants are acrid; but the

tuberous roots contain much starch. This is extracted (by washing the roots of *Tacca pinnatifida*) by the inhabitants of Tahiti and other islands of the South Sea, who use the meal for bread, cultivating the plant in fields. This species, and *T. dubia, montana,* and others, are used in like manner in Malacca, the Moluccas, Cochin China, &c., and are sometimes eaten raw with an acid, which neutralizes the acridity.—Genera: *Tacca,* Forst.; *Ataccia,* Presl.

DIOSCOREACEÆ (YAMS) are plants with twining stems rising from large tuberous or knotted woody root-stocks, with broad netted-veined stalked leaves, small diœcious 6-androus regular flowers, the tube of the 6-parted perianth adhering in the fertile flowers to the 3-celled ovary; styles 3, distinct or deeply trifid; ovules 1–2 in a cell; stamens of the barren flower 6, on the perianth; fruit a 3-celled (or by suppression 1-celled) dehiscent capsule, or a succulent berry; seeds with a small embryo in a cavity in the hard perisperm.—Illustrative Genera: *Tamus,* L.; *Dioscorea,* L.

Affinities, &c.—Very near to Smilaceæ, from which they differ in the inferior ovary and the cavity in the perisperm; the mostly capsular fruit is replaced by a berry in *Tamus,* like that of *Smilax,* but inferior instead of superior. The epigynous condition relates these plants to Amaryllidaceæ. Some authors consider they are related to Aristolochiaceæ; but it is a distant affinity.

Distribution.—A rather large group, chiefly tropical; *Tamus communis* is British.

Qualities and Uses.—The sap is often more or less acrid; but the tubers formed by certain species of Yams (*Dioscorea sativa, alata,* and *aculeata*) contain abundance of starch; so that under cultivation, and after cooking, when the noxious principle is dissipated, they become valuable articles of food. The tubers of other *Dioscoreæ* are unfit for food; and those of *Tamus communis,* Black Bryony, have acrid, purgative, and emetic properties. *Testudinaria elephantipes,* a Cape plant, in cultivation in our Botanic gardens, produces a remarkable tuberous growth, resembling a rugged stump of an old tree, covered by a kind of false bark, which is tessellated with large compound angular facets; its internal substance is eaten by the Hottentots.

ORCHIDACEÆ. ORCHIDS.

Coh. Orchidales, *Hook.*

Diagnosis.—Herbs, distinguished by their irregular flowers, 6-merous perianth inseparate at the base from the ovary; stamen (1, or very rarely 2) gynandrous, pollen cohering in waxy or mealy masses; ovary inferior, placentas parietal.

Character.

Perianth mostly petaloid, adherent, in two circles; the outer circle of three pieces (*sepals*), distinct or more or less coherent below,

two lateral and one anterior (or posterior when the ovary is twisted); the inner circle of three pieces (*petals*), or rarely one, alternate with the sepals, two lateral, and one (the *labellum*) posterior (or, by the twisting of the ovary, anterior) (figs. 458, 459, 461, & 462), usually longer and larger than the others, variously

Fig. 458.

Fig. 459.

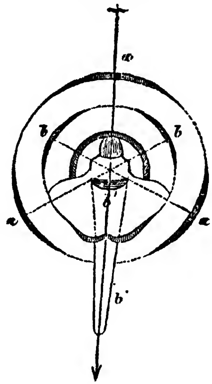


Fig. 460.

Fig. 458. Flower of *Orchis*, and
Fig. 459. Diagram of ditto: *a*, *a*, *a*, sepals; *b*, *b*, petals; *b'*, labellum; *b''*, spur.
Fig. 460. Clavate pollen-mass and caudicle of *Orchis*.

formed, with or without appendages, sometimes divided into 3 regions by contractions, forming *hypochilium* (at the base), *mesochilium*, and *epichilium*; free, or more or less adherent to the *column*. *Stamens* gynandrous, the filaments confluent with the style into a *column* (fig. 463), bearing mostly 1 perfect *anther* on the side turned away from the labellum, with two lateral processes (abortive anthers), or, rarely, 2 perfect lateral *anthers* with an abortive process next the odd sepal (*Cypripedium*); *pollen* pulverulent, or in grains, more or less coherent, or in waxy masses which are free or provided with a pedicel or *caudicle* (fig. 460), which adheres to a gland or glands at the apex or *rostellum* of the stigma. *Ovary* inferior, often twisted, 1-celled, with 3 double parietal placentas bearing numerous anatropous ovules; *style* 1, confluent with the filaments into the *column*, which is surmounted by a 3-merous, mucous, discoid *stigma* facing the labellum, its lobes alternating with the lines of placentation; the lateral lobes usually abortive, but sometimes forming divergent processes, the odd lobe more or less developed into a beak (*rostellum*) bearing 1 or 2 glands. *Fruit* mottly a capsule bursting by 3 valves, bearing the placentas in the middle, separating from the midribs of the carpels, which remain as an open framework;

rarely a fleshy indehiscent pod; *seeds* very numerous and extremely small, consisting of a cellular nucleus without distinct radicle or plumule, enclosed in a loose membranous or rarely crustaceous testa.

The Order has been divided by Lindley, its greatest exponent, into several tribes, according to the number and position of the anthers, the number and nature of the pollen-masses, &c.

1. Anther solitary.
   - A. *Pollen-masses waxy.*
     - *a.* No caudicle or separate stigmatic gland . . Tribe MALAXEÆ.
     - *b.* A distinct caudicle, but no separate stigmatic gland . . . . EPIDENDREÆ.
     - *c.* A distinct caudicle and stigmatic gland . . . . VANDEÆ.
   - B. *Pollen powdery, granular, or sectile.*
     - *a.* Anther terminal, erect . . . . OPHRYEÆ.
     - *b.* Anther terminal, opercular . . . . ARETHUSEÆ.
     - *c.* Anther dorsal . . . . NEOTTEÆ.
2. Anthers two . . . . CYPRIPEDIEÆ.

Affinities, &c.—In the greater part of the genera the Monocotyledonous type is departed from in several particulars, as:—in a more or less considerable irregularity of the perianth, especially in the condition of the *labellum*; in the circumstance that the filaments are confounded with the style into a central organ, prolonged from the inferior ovary, called the *column*, and that generally 2 out of 6 (at least 3) anthers, are abortive, while the pollen is frequently less developed than usual, the process of subdivision into distinct cells or granules being arrested, so that it remains in compound masses of various degrees of magnitude and of more or less firm and even waxy consistence. In some cases, however, as in *Thelymitra*, the perianth is almost regular, so as to resemble that of some of the genera of Iridaceæ; and in *Cypripedium* we find 2 anthers developed and the rest abortive. Among the other remarkable peculiarities of the structure are processes of various kinds occurring upon the column and labellum, which there is reason to regard as indications of abortions of staminal organs. These have given rise to the opinion that the elements of 2 circles of stamens exist in this Order, of which 5 are usually suppressed, the perfect one belonging to an external circle of 3, while in *Cypripedium* the 2 which are developed are members of the inner circle of 3, one of which, with the entire outer circle, is abortive. The position of the organs may be thus shown:—In the typical flower the arrangement would be $S\ {.}{\cdot}{.}\ P\ {\cdot}{.}{\cdot}\ A\ {.}{\cdot}{.} + {\cdot}{.}{\cdot}\ \overline{G\ {.}{\cdot}{.}}$ In most Orchids the arrangement is $|\ S\ {.}{\cdot}{.}\ P\ {\cdot}{.}{\cdot}\ A\ {}_{\circ}{\cdot}_{\circ} + {}^{\circ}{}_{\circ}{}^{\circ}\ \overline{G\ {.}{\cdot}{.}}$, the dots representing those organs that are present and their relative position, the circles those organs that are suppressed. In *Cypripedium* the formula is $S\ \overline{{.}{\cdot}{.}}\ P\ {\cdot}{.}{\cdot}\ A\ {}_{\circ}{}^{\circ}{}_{\circ} + {\cdot}_{\circ}{\cdot}\ \overline{G\ {.}{\cdot}{.}}$. These views are supported by numerous exceptional instances, in which some or all of the ordinarily suppressed stamens are present, and by the anatomical construction, which reveals the existence of as many bundles of vascular tissue in the column and ovary as there are stamens and carpels. *Thelasis* has normally three stamens. The suppression of 2 out of 3 stamens connects this Order with Marantaceæ and Zingiberaceæ, where the same phenomenon exists in a different modi-

fication, as mentioned under those Orders; the Apostasiaceæ have 2 stamens only, with their filaments adhering to the lower part of the style. The ovary is apparently formed of 3 carpels, with the stigmas simple. Since they alternate with the placentas, Lindley supposes the ovary to be formed of 6 carpels, 3 fertile and 3 barren; but this seems contrary to analogy and without sufficient independent support. In Apostasiaceæ, Marantaceæ, and Zingiberaceæ the ovary is 3-celled, or sometimes imperfectly so in the last, from the margins not meeting in the centre. *Selenipedium* has a 3-celled ovary. The seeds, which are very minute, are of simple organization: the ovules, at the time of fertilization, consist solely of an embryo-sac with 2 integuments; and the ripe seed presents an embryo devoid of distinct organs (cotyledon and radicle), enclosed in a loose testa —in this respect exhibiting a relationship to Burmanniaceæ.

Fig. 461.

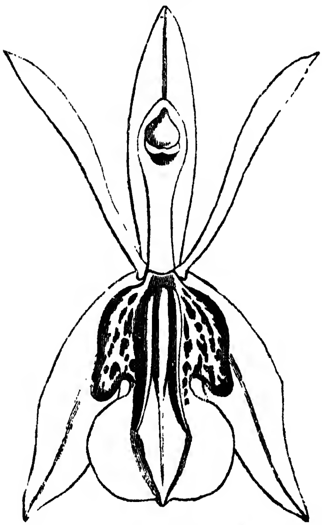


Fig. 462.

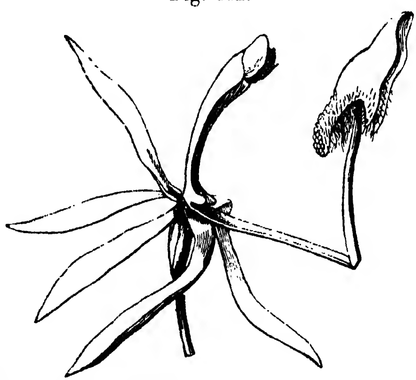
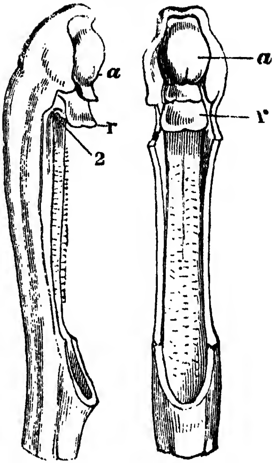


Fig. 461. Orchid flower, showing the parts of the perianth and column.
Fig. 462. Flower of *Drakea*: the parts of the perianth are turned back to show the column and the lip, which is jointed in the middle, and endowed with hinge-like motion when irritated; so that an insect alighting on it is entrapped, and in its struggles to escape removes the pollen-massses.

The labellum sometimes exhibits irritability, moving spontaneously or when touched (*Megaclinium*, *Bolbophyllum*, *Drakea*, &c.) (fig. 462): its forms are most varied and strange, often causing the entire flower to resemble an insect or some other living object. The rostellum and stalk of the pollen-masses are also endowed with contractile properties. In *Catasetum* these are so powerful as to cause the sudden forcible ejection of the pollen-masses from the anther-cells, when the rostellum or other sensitive organ is touched, as by the proboscis of an insect. Insects visiting the flowers of our common English Orchis, for the sake of the honey, come into contact

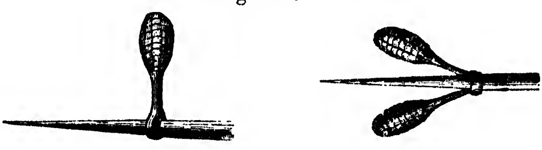
with the rostellum, and thus liberate the pollen-masses. These latter adhere firmly to the insect's back by means of a gland at the end of the stalk, so that the pollen-mass is conveyed to another flower. It must, however, be remarked that if the pollen-mass retained the nearly vertical direction it had on its exit from the anther, it would, when introduced by the insect into another flower, strike against the anther, and not against the stigma. In order to place the pollen in such a position that it shall impinge on the stigma, the caudicle or stalk of the pollen-mass contracts so as to give the pollen-mass the requisite horizontal direction. This movement can readily be seen by thrusting the point of a pencil into a flower against the rostellum, when the pollen-masses will adhere to the pencil, and may be withdrawn from the anther-case, and, if watched, will be seen to bend downwards, in the manner just described, immediately after their removal from the anther (fig. 464). These movements will be again alluded to in the physiological portion of this work.

Fig. 463.



Column of *Vanilla* from the front and from the side, the parts of the perianth cut away: *a*, the anther; *r*, the rostellum; the 2 points to the stigma.

Fig. 464.



Orchis pyramidalis; *a*, pollen-mass just removed from the anther, vertical; *b*, pollen-masses divergent and horizontal.

Two distinct forms of the perianth sometimes present themselves on the same flower-spike, so that the same species has received two specific titles, and even three distinct generic names:—e. g., *Monachanthus*, *Myanthus*, and *Catasetum*, now all included in the last named genus, and *Cycnoches ventricosum* and *Egertonianum*, now known to be forms of one and the same species. This was considered a most anomalous circumstance till it was shown by Darwin that the different forms represented different sexes, the male flowers being different from the female.

The Orchidaceæ are terrestrial in temperate climates, forming subterraneous tubers or tuberously enlarged fibrous roots, from which the flowering-stem shoots up afresh every season. In warm and moist climates they are very frequently epiphytic, hanging on the branches of trees, or even attaching themselves to rocks and other foreign objects. These kinds generally form some kind of stem-tuber, either from the lower internodes of the axis which has just flowered, or of a new axis, sometimes from the

whole of the internodes of a long jointed leafy axis, &c. The roots which hang down from them are soft and delicate at the apex; and the epithelial cells exhibit spiral-fibrous thickening of a peculiar kind. *Angræcum funale* has neither true roots nor leaves. *Neottia nidus avis* has buds on the extremity of the roots (Van Tieghem). *Epipogon Gmelini* and *Corallorhiza innata* are also rootless. The embryo is a mere cellular globule borne on a suspensor.

Distribution.—Orchids are very numerous, and occur in almost all parts of the globe, except the very coldest or in very dry regions. In temperate climates they occur chiefly in shady woods, damp pastures, or open calcareous downs; but they are most abundant in damp situations in the tropics.

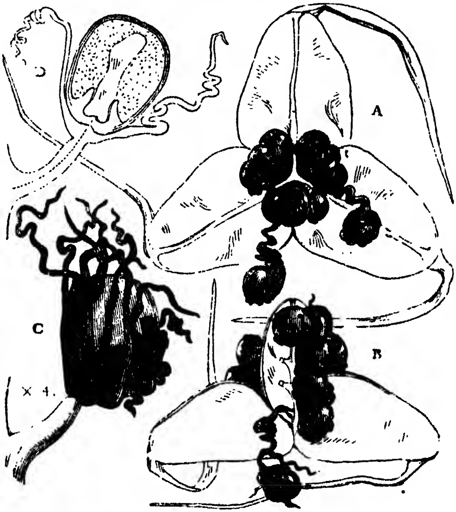
Qualities and Uses.—The properties of these plants are generally unimportant. The subterranean tubers of some form nutritious food, from the presence of a gummy substance: that of a native species, *Orchis mascula*, was formerly collected and sold for the preparation of Salep; and other kinds are eaten in India. Some of the South-American yield a kind of vegetable glue; *Aplectrum hyemale*, the North-American Putty-root, is used for making a cement for china. The most important plants, perhaps, are *Vanilla planifolia* and other species, and a species of *Sobralia*, the dried pulpy pods of which furnish the Vanilla used for flavouring chocolate and confectionary. A few others are described as having medicinal properties of various kinds.

Apostasiaceæ is a small Order of perennial herbs nearly related to Orchidaceæ, bearing a regular perianth and 2 or 3 stamens which are confluent by their filaments with the lower part of the style (the anthers free), forming a kind of column, prolonged above into a filiform process with a 3-lobed stigma; ovary 3-celled, with axile many-seeded placentas; seeds apparently as in Orchidaceæ.—These plants differ from Orchids chiefly in the free condition of the upper part of the style and the 3-celled ovary; but as the latter character is inconstant in some Monocotyledonous Orders, probably this Order should be united with Orchidaceæ; they are near to Burmanniaceæ also; but that Order has free stamens. Lindley regards this Order as connecting Orchidaceæ with Amaryllidaceæ through Hypoxidaceæ. They are natives of damp woods in tropical India, and are without known properties.—Genera: *Apostasia*, Bl., &c.

Burmanniaceæ are small annual herbs, often with minute and scale-like leaves, or those near the root grass-like; the flowers perfect, with a 6-cleft petaloid perianth, the tube of which adheres to the 1-celled or 3-celled ovary; stamens 3, distinct, introrse, and superposed to the inner segments of the perianth, or 6 and extrorse; stigmas 3; capsule many-seeded; the seeds very minute, with a homogeneous nucleus in a loose membranous testa.—Natives of the tropics of America, Africa, and Asia. Some are probably parasitical. The affinities of these plants are rather obscure; they apparently agree with Iridaceæ in the character of the flowers, but differ in the position and number of the stamens; while, by the seeds resembling those of Orchidaceæ, they form a connecting link between these two Orders. They are also related through Taccaceæ to Aristolochiaceæ. They are said to be bitter and astringent, but are unimportant in these respects.—Genera: *Burmannia*, L.; *Thismia*, Griff., &c.

ZINGIBERACEÆ (THE GINGER ORDER) consist of herbaceous perennials with a creeping rhizome; leaves broad, with a sheathing petiole, and numerous parallel veins diverging from a midrib; flowers spiked or racemose, with spathaceous membranous bracts; perianth adherent, irregular, in three circles each of three parts, one petal being larger in each of the two inner circles; stamens 3, distinct, 2 abortive, and the fertile one posterior, opposite the labellum or large segment of the innermost perianthial whorl; anther 2-celled; ovary 3-celled, or with the dissepiments imperfect; seeds numerous, often arillate, with the embryo in a sac (*vitellus*) within the perisperm.—Illustrative Genera: *Zingiber*, Gærtn.; *Amomum*, L.; *Hedychium*, Kœnig; *Alpinia*, L.; *Costus*, L.

Fig. 465.



Hedychium: A, B, loculicidal capsule; C, seed with arillus; D, section of seed.

Affinities, &c.—This Order is nearly related to Marantaceæ, Orchidaceæ, and the allied Orders, but may always be distinguished by the only fertile stamen being situated next the axis (posterior), not next the bract (anterior) as it is in Orchidaceæ (before the ovary becomes twisted), or lateral as it is in Marantaceæ; the ovary is usually 3-celled, like that of Marantaceæ, but the embryo is contained in a special sac or vitellus, which is not present in the seeds of either Marants or Orchids.

Distribution.—A large Order, consisting mostly of tropical plants; the greater part East-Indian, but a few occurring in America, in Africa, and in Japan.

Qualities and Uses.—Remarkable for the pleasant aromatic and stimulant qualities of the rhizomes and the seeds of many kinds; some are

astringent, many yield starch, and some colouring-matters. Ginger is the rhizome of *Zingiber officinale*: preserved ginger is made from the younger parts of the rhizomes. Cardamom seeds are obtained from *Amomum Cardamomum* (Round Cardamoms), *A. angustifolium* (Madagascar Cardamoms), *A. maximum*, *A. aromaticum*, *Elettaria major* (Ceylon), and *E. Cardamomum* (Malabar). Turmeric consists of the yellow-coloured rhizomes of *Curcuma longa*; the starchy rhizomes of some East-Indian species of *Curcuma* furnish Arrow-root. Galangale-root, which has properties resembling those of Ginger, consists of the rhizomes of *Alpinia Galanga* and *racemosa*; Zedoary, of those of *Curcuma Zedoaria* and *Zerumbet*. *Amomum Grana Paradisi* yields the Grains of Paradise, used as stimulants, and also for giving pungency to spirits and beer. Many of the species have very beautiful blossoms, and are cultivated in stoves on that account. The bright colouring is found sometimes in the bracts, sometimes in the perianth, as in *Hedychium coronarium*.

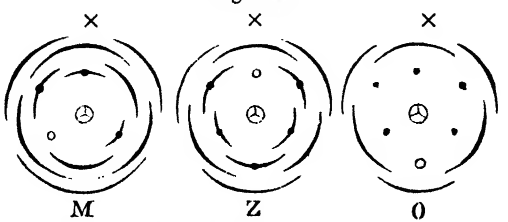
MARANTACEÆ. The Arrowroot Order.

Coh. Amomales, *Benth. et Hook.*

Diagnosis.—Herbaceous plants with creeping rhizomes, resembling Zingiberaceæ in habit, but with the perianth more irregular, and the inner segments often abortive; of the 6 stamens 5 are petaloid, and 1 lateral fertile 2-lobed, with a 1- (2?)-celled anther on one of its lobes; ovary inferior, 1–3-celled, with numerous perispermic seeds; embryo not enclosed in any special sac.—Illustrative Genera: *Maranta*, Plum.; *Canna*, L.

Affinities, &c.—The affinities of this Order, often called Cannaceæ, are those of Zingiberaceæ, from which this Order is separated by the place of its fertile stamen (lateral) and by the absence of a vitellus or special sac

Fig. 466.



Diagrams of the flowers of Marantaceæ (M), Zingiberaceæ (Z), and Orchidaceæ (O). The small open circles are fertile stamens; the black dots abortive stamens; the black dots with the broad line scored through are petaloid stamens. The × indicates the position of the axis, the bract being exactly opposite.

round the embryo. If we assume the Orchidaceæ, as mentioned under that Order, to have the rudiments of a double series of stamens, the relations of Orchidaceæ, Zingiberaceæ, and Marantaceæ are very close, and yet their distinctions very clear (fig. 466).

Orchidaceæ, with a double perianth and two circles of stamens, have the anterior stamen (belonging to the outer circle) developed, the rest abortive, or present in the form of horns, ridges, &c. (O); or, in *Cypripedium*, they have the two lateral stamens of the inner circle developed, the anterior and all those of the outer circle abortive.

Zingiberaceæ, with a double perianth, have the outer circle of stamens petaloid, forming a third perianthial circle, the odd (posterior) stamen of the inner circle developed, the 2 lateral abortive (Z).

Marantaceæ, with a double perianth, have the outer circle of stamens more or less developed in a petaloid form, as a third perianthial circle, and one lateral stamen of the inner circle fertile—the other lateral stamen, with the posterior one, being abortive (M). Dr. Dickie has lately shown that the anther of *Canna* is in reality 2-celled.

Eichler gives a different explanation of the flowers of these plants. According to him the flower of *Canna* consists of 5 ternary verticils alternating one with another, the two outer constituting the perianth, the two following ones the andrœcium, and the last the pistil. The perianth and pistil are complete, but the outer whorl of the andrœcium is completely suppressed, as is also one stamen of the inner whorl. Of the two remaining stamens of this inner whorl, one has half an anther only, the other is entirely petalodic. This second whorl of the andrœcium also furnishes accessory appendages of different shapes in various genera. In Zingiberaceæ the outer whorl of stamens is suppressed, but the inner whorl is complete, though there is only one perfect stamen, and this has two anther-lobes. In Musaceæ the inner row of the andrœcium is complete, and only one member of the outer one is deficient. In *Cypripedium* there is one member of the outer row present as a staminode and two of the inner. In Xyrideæ, Burmanniaceæ and some Eriocaulons, the inner whorl is complete and perfect. In Irids, Grasses, and most Orchids the inner whorl is suppressed.

Distribution.—The species are numerous, and natives chiefly of tropical America, Africa, and India.

Qualities and Uses.—The abundance of pure starch furnished by the rhizomes of many species constitutes the principal feature of the Marantaceæ considered from an economical point of view. True Arrowroot is obtained from *Maranta arundinacea*, *Allouyia*, and *nobilis* (West Indies), and *M. ramosissima* (East Indies). Tous-les-Mois is derived from species of *Canna*, probably *C. coccinea*, *Achiras*, *edulis*, &c. *Canna indica* is called "Indian shot," from its beautifully spherical seeds. Some of the species are cultivated in our stoves. Many of the species of *Calathea* and *Maranta* have beautifully coloured foliage.

MUSACEÆ (Bananas) are large herbaceous plants with long sheathing petioles forming a spurious stem; leaves large, with a strong midrib and parallel lateral veins; flowers enclosed in a spathe, hermaphrodite; perianth more or less irregular, adherent, petaloid, in two 3-merous rows; stamens 6, on the segments of the perianth, some always abortive; anthers 2-celled; ovary 3-celled, many-seeded, or rarely 3-seeded; fruit a capsule or succulent and indehiscent; embryo at the end of perisperm.—Illustrative Genera: *Heliconia*, L.; *Musa*, Tournef.; *Strelitzia*, Banks; *Ravenala*, Adans.

Affinities, &c.—With certain well-marked differences, these plants approach in some degree to the Marantaceæ and Zingiberaceæ in habit, especially in the character of the foliage, but the Musaceæ have 5 or 6 more or less perfect stamens and no staminodes; from the Amaryllidaceæ, which they resemble in the epigynous hexandrous structure, they differ in the irregular flowers, the general habit, and the character of the bracts or spathes.

Distribution.—A small Order, the species of which are generally diffused, wild or in culture, in the plains of the tropics and subtropical regions of the globe.

Qualities and Uses.—These plants are most valuable as sources of food and fibrous materials. *Musa paradisiaca*, the Plantain, and *Musa sapientum*, the Banana, are plants bearing gigantic leaves on long petioles, the imbricated sheaths of which form a pseudo-stem many feet high. They produce large clusters of pulpy fruit containing much sugar and starch, which form a very important article of food in the tropics. Several other species of *Musa* yield similar fruits. The leaves are used for thatching huts, or split up for plaited work of all kinds. The fibre of the petioles is a valuable material, especially that of *Musa textilis*, which is known as Manilla Hemp. The young shoots are also eaten boiled. *Ravenala speciosa* has an edible seed; a quantity of watery juice exudes from its petioles when cut, whence it has been called *Arbre du voyageur*. *Strelitzia* is a genus with very handsome flowers, several species of which, as also of *Musa*, are often cultivated in stoves.

AMARYLLIDACEÆ. Amaryllids.

Coh. Narcissales, *Hook.*

Diagnosis.—Chiefly bulbous and scape-bearing herbs, not scurfy or woolly, with linear flat root-leaves, and perfect, regular (or nearly so), 6-androus flowers; perianth petaloid, 6-parted, its tube inseparate from the 3-celled ovary; the segments of the limb imbricated or valvate in æstivation; anthers introrse; fruit a 3-valved, loculicidal capsule or a 1–3-seeded berry; seeds with fleshy or horny perisperm; radicle turned to the hilum.—Illustrative Genera: Tribe 1. Amarylleæ. Bulbous plants, without a coronet. *Galanthus*, L.; *Amaryllis*, L.—Tribe 2. Narcisseæ. Bulbous plants, with a coronet in the perianth. *Pancratium*, L.; *Narcissus*, L.—Tribe 3. Alstrœmerieæ. Fibrous-rooted; no coronet. *Alstrœmeria*, L.—Tribe 4. Agaveæ. Fibrous-rooted; sepals and petals alike, valvate in æstivation; no coronet. *Agave*, L.; *Fourcroya*, Vent.

Affinities, &c.—The floral formula may be represented as follows:—
$\mid P\ 3+3\ A\ 3+3\ \overline{G}\ 3$. This epigynous Order contrasts with the hypogynous Liliaceæ; among its epigynous allies, Iridaceæ are distinguished by their 3 stamens and extrorse anthers: its nearest allies are Hæmodoraceæ and Hypoxidaceæ, the characters of which are given elsewhere. The coronet of the *Narcisseæ* is sometimes regarded as a circle of abortive stamens, but is more probably an outgrowth from the tube of the perianth.

Distribution.—A large Order, the species of which are generally diffused, but which, like Iridaceæ, have their maximum at the Cape of Good Hope. The *Narcisseæ* are common in Europe, while the genera unprovided with a coronet are very rare in Europe and North America, but abound in South Africa.

Qualities and Uses.—The Amaryllidaceæ are commonly characterized by active properties, the *Amarylleæ* and the *Narcisseæ* especially being emetic and purgative, and even poisonous; the juice of the bulb of *Hæmanthus toxicarius* is used by the Hottentots to poison arrows. The Snowdrop (*Galanthus nivalis*), Snowflake (*Leucojum vernum*), the Daffodil (*Narcissus Pseudo-Narcissus*), with the other cultivated *Narcissi*, *Pancratium maritimum*, &c., act as emetics. Others are astringent; but starch is washed from the roots of some species of *Alstræmeria*. The *Agaves* are exceedingly valuable plants, having abundant innocuous saccharine sap, and large leaves containing excellent fibre. *Agave americana*, called by mistake the American Aloe, is the Hundred-years plant; but the statement that it lives 100 years before flowering is fabulous: it is a native of America, but is naturalized in some parts of S. Europe, and is planted, on account of its large spiny leaves, to form fences. From this and other species is obtained Pita thread, a valuable fibre; Pulque (a fermented liquor) and a brandy distilled from this are made by cutting the buds out of *Agave*-plants and collecting the sap, which exudes in great abundance when this operation is performed just before the flowering stem is pushed out; these plants are also called Maguey-plants. This Order affords a number of beautiful flowers, more permanent than Iridaceæ, and often attaining a very large size. Most of them are annual flowerers; but the *Agaveæ*, having remarkable foliage, like that of the *Aloes* in Liliaceæ, produce flowering stems (sometimes many feet in height) after vegetating for a number of years, whence the story of the Hundred-years Aloe. *Sternbergia lutea* is supposed to be the Lily of the fields referred to by Christ.

Hypoxidaceæ are a small Order of epigynous Monocotyledons, nearly related to Amaryllidaceæ, but differing in their habit, having hairy foliage and no bulbs, and in their usually strophiolate seeds having the radicle distant from the hilum. The 6 stamens, the imbricated, distinctly petaloid perianth, and the habit of the foliage separate them from Iridaceæ.—They occur scattered in the warmer parts of the globe, and are apparently more or less bitter and aromatic. The tubers of some are eaten.—Genera: *Curculigo*, Gærtn.; *Forbesia*, Eckl.; *Hypoxis*, L.; *Sauridia*, Harv.

Hæmodoraceæ are herbs with fibrous roots, usually equitant leaves, and perfect 3–6-androus regular flowers, which are woolly or scurfy outside; the tube of the 6-parted perianth adherent to the whole surface, or merely to the lower part of the 3-celled ovary; anthers introrse; stamens superposed to the petals when 3; seeds with cartilaginous perisperm; radicle remote from the hilum.—The structure of the genera included in this Order is rather irregular: from Amaryllidaceæ they are usually distinguished by the woolly tubular perianth, the equitant leaves, and, in some cases, by the 3 stamens; but none of these characters are without

exception; from Iridaceæ the triandrous genera differ in the stamens being introrse and superposed to the petals, which last character also separates them from Hypoxidaceæ. The radicle is said to be remote from the hilum, as in Hypoxids; while it is next it in Amaryllids and Irids. The *Vellozicæ* and *Barbaceniæ* are more or less arborescent, and in some degree branched, especially the former, which have a very remarkable aspect; in many respects they approach Bromeliads.—The plants are natives of America, the Cape, and Australia, and have sometimes bitter and astringent properties, as *Aletris farinosa*. The roots often contain a red matter available as a dye, whence the name of Blood-roots; *Lachnanthes tinctoria* is used in America for dyeing. The roots of several species of *Hæmodorum* are eaten, roasted, by the natives of Australia.—Genera: *Hæmodorum*, Sm.; *Aletris*, L.; *Vellozia*, Mart.; *Barbacenia*, Vandelli.

IRIDACEÆ. The Flag Order.

Coh. Narcissales, *Benth. et Hook.*

Diagnosis.—Herbs with bulbs, corms, or rhizomes, equitant, 2-ranked leaves, and perfect, regular or irregular flowers: the segments of the 6-parted petaloid perianth (fig. 467) convolute in

Fig. 467.

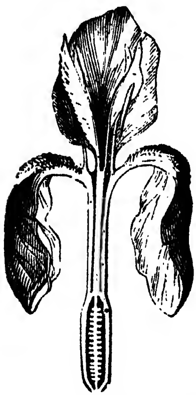


Fig. 468.

Fig. 469.

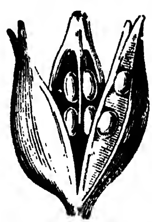


Fig. 470.

Fig. 471.

Fig. 467. Vertical section of the flower of *Iris*: *a*, inferior ovary.
Fig. 468. Stigmas of *Crocus*.
Fig. 469. Loculicidal capsule of *Iris* burst.
Fig. 470. Plan of ditto.
Fig. 471. Section of seed of *Iris*.

the bud in 2 circles; the tube inseparate from the 3-celled ovary; stamens 3, superposed to the outer segments of the perianth, distinct or monadelphous; anthers extrorse; style 1; stigmas 3 (fig. 468), often petaloid (*Iris*); capsule 3-valved, loculicidal (figs.

469 & 470); seeds with horny or hard fleshy perisperm (fig. 471).—Illustrative Genera: *Iris*, L.; *Tigridia*, Juss.; *Gladiolus*, Tournef.; *Ixia*, L.; *Crocus*, Tournef.

Affinities, &c.—The tribes of this Order (IXIEÆ, IRIDEÆ, and GLADIOLEÆ) are distinguished by the regular or irregular perianth, the free or inseparate stamens, the filaments equal or unequal in length, the form of the stigma, &c. The floral formula is | P 3+3 A 3 G 3. Among the epigynous petaloid Monocotyledons, the Iridaceæ approach, by genera like *Crocus*, the Amaryllidaceæ, which, however, have 6 introrse stamens. The same character separates the epigynous Bromeliaceæ, which have some affinity with this family; one plant of this Order, *Eleutherine anomala*, has, however, been described as having six stamens, probably as an accidental occurrence. Orchidaceæ differ in the gynandrous structure; Marantaceæ and Zingiberaceæ in their monandrous state, as also in the character of their foliage. The little Order Burmanniaceæ resembles Iridaceæ in many particulars, but differs in some essential points mentioned under that order; and this is the case also with Xyridaceæ. *Gladiolus* has slightly irregular flowers; *Crocus* has quite a regular perianth; *Iris* has also regular flowers, the seeming irregularity being dependent on the reflexed petals and the large petaloid styles which conceal the stamens.

Distribution.—A large Order, diffused throughout temperate and warm climates, but especially abundant at the Cape of Good Hope.

Qualities and Uses.—The sap of many of these plants is more or less acrid, purgative, or emetic, as that of the Flags (*Iris*) generally, *Ferraria*, *Sisyrinchium*, &c. Saffron consists of the stigmas of the Saffron Crocus (*C. sativus*) and of *C. odorus* (Sicily). Orris-root, used in perfumery, is the rhizome of *Iris florentina*. The genera of this Order contribute a large share to our collections of garden-bulbs, as will be recognized from the plants already named; they are more remarkable for their beautiful but transient flowers than for any useful quality; the corms and rhizomes of some are said to be eaten, on account of the starch they contain, by the Hottentots and other races.

BROMELIACEÆ. THE PINEAPPLE ORDER.

Coh. Amomales, *Hook.*

Diagnosis.—Herbs (or scarcely woody plants), nearly all tropical, the greater part epiphytes, with persistent dry or fleshy and channelled crowded leaves, sheathing at the bases, usually covered or banded with scurfy scales; perianth free or adherent, in two circles, the outer (sepals) often coherent, and differently coloured from the inner (petals), which are distinct and imbricated; stamens 6; ovary 3-celled, with numerous ovules on axile placentas; style single; stigma 3-lobed or entire, often twisted; seeds numerous, with a minute embryo in the base of mealy perisperm; the radicle next the hilum.—Illustrative Genera: *Ananassa*, Lindl.; *Bromelia*, L.; *Æchmea*, R. & P.; *Billbergia*, Thunb.; *Pitcairnia*, Hérit.; *Tillandsia*, L.

Affinities, &c.—Among the Bromeliaceæ are found both epigynous and hypogynous genera, as well as forms with a partially adherent perianth; on the whole, the tendency is to the former condition, whence the Order must be regarded as an ally of Amaryllidaceæ, from which it differs in habit and in the mealy perisperm; from Iridaceæ it differs in these particulars and in the 6-androus stamens, while the style and stigma are somewhat similar. The character of the habit, and the often distinctly characterized calyx and corolla, offer a resemblance to Hydrocharidaceæ, which, however, have aperispermic seeds. The fruit varies much in this Order, being commonly capsular; but in *Ananassa* the entire spike of inflorescence, together with the stem, becomes blended into a succulent sorosis, forming the fruit of the well-known Pine-apple. The scurfy epidermis of the leaves displays a very interesting microscopic structure.

Distribution.—A considerable group, the members of which are, for the most part, natives of tropical America; but some are now naturalized in West Africa and the East Indies.

Qualities and Uses.—Chiefly important for the fruit of *Ananassa*, fibres, colouring-matters, and other economic products. *Bromelia Pinguin* is used as a vermifuge in the West Indies. Many of these plants grow upon the branches of trees (epiphytic), and they appear to be capable of obtaining the greater part of their nourishment from the atmosphere; their rigid, tough epidermis enables their succulent leaves to withstand the influence of a hot and dry atmosphere. *Tillandsia usneoides*, called Old-Man's Beard, is a common plant, forming a dense mass of dark-coloured fibres, which hang down from the boughs of the trees of the forests of tropical America, as Lichens do in colder climates. Most of the genera have brilliantly coloured flowers, sometimes in tall racemes and panicles, whence they are much esteemed as ornamental stove-plants.

HYDROCHARIDACEÆ are aquatic herbs, with diclinous or polygamous regular flowers issuing from a spathe on the end of scape-like peduncles; floral envelopes in a single or double circle, in the fertile flowers united into a tube and inseparate from the 1–9-celled ovary; placenta parietal; seeds without perisperm.—Illustrative Genera: *Udora*, Nutt.; *Vallisneria*, Mich.; *Stratiotes*, L.; *Hydrocharis*, L.

Affinities, &c.—The sum or combination of the characters of this interesting Order keeps it apart from all other Monocotyledons, while the characters taken separately connect it with many. The inferior ovary and, in the case of *Stratiotes*, the habit connect them with Bromeliaceæ; the 3-merous petaloid flower and aperispermic seeds with Alismaceæ; the 3-merous petaloid flower and 3-carpellary ovary with the Commelynaceæ, which, however, with a superior ovary, like the Alismaceæ, have perispermic seeds. The inferior ovary, numerous seeds, and general characters remove them from Naiadaceæ, with which they are often associated by habit, and the Araceæ, with which some would connect them; their spathe is scarcely more Araceous than that of Amaryllidaceæ. *Vallisneria* and *Elodea* (*Anacharis*) are plants well known to microscopists for the favourable opportunities they offer of examining the rotation of the protoplasm of the cells. *Hydrocharis*, a plant somewhat like a miniature Water-lily, is common in fresh-water ditches; and its sepals and rootlets are equally

adapted for the microscopic investigation of living tissues. *Elodea canadensis* is the American Water-weed, which has increased so rapidly in our canals and ditches since its introduction from America some years since.

Distribution.—The species are not numerous; they are found in fresh water in Europe, N. America, E. Indies, and New Holland.

Properties and Uses.—They appear to have no very active properties. *Hydrocharis* is said to be astringent.

Series 2. Coronarieæ.

Flower-tube free from the ovary.

A. Syncarpiæ.

Carpels united; seed usually perispermic.

PHILESIACEÆ are climbing or erect shrubs with coriaceous, netted-ribbed leaves and large and showy perfect flowers with a 6-merous perianth in two circles, equal, or the calyx much shorter; stamens 6, adherent to the perianth at the base; ovary 1-celled, with 3 parietal placentas; ovules semianatropous (not orthotropous, as is commonly stated).—These plants, consisting of *Lapageria rosea*, a climbing shrub with beautiful crimson flowers and basifixed anthers, and *Philesia buxifolia*, the flowers of which differ chiefly in the marked difference of calycine and corolline circles and the mode of union of the bases of the filaments and versatile anthers, differ from Liliaceæ chiefly in the parietal position of the placentas; in habit *Lapageria* is related to *Smilax*, and is in some measure intermediate between Smilaceæ and Liliaceæ. They are Chilian plants, now in cultivation with us. *Lapageria* bears sweet edible berries.

ROXBURGHIACEÆ consist of 4 species of *Roxburghia*, twining shrubs with broad leathery leaves and tuberous roots, from the hotter parts of the East Indies. Their habit connects them with Smilaceæ; but their perianth is composed of 4 petaloid pieces, and they have 4 stamens with enlarged connectives (each set of organs, according to Griffith, in 2 dimerous circles), and the 1-celled ovary (formed of 1 carpel, according to Griffith) has numerous anatropous ovules arising from the base of the cavity; the sessile stigma is penicillate. The fruit is 2-valved, with 2 clusters of seeds attached on long cords; embryo in the axis of fleshy perisperm. The affinities of these plants are not clear; but the resemblance is perhaps greater to *Paris* than to any other genus that can be named.

SMILACEÆ (the Sarsaparilla Order) consists of herbs or climbing shrubby plants with stalked netted-veined leaves, regular perfect or diœcious flowers, with the 6–10-parted perianth of the fertile flowers free from the 3–5- (rarely 1–2-) celled ovary; stamens 6–10, introrse; anthers adnate, basifixed; styles or sessile stigmas as many as the cells of the ovary, and distinct; fruit baccate, with few or several seeds; ovules ortho-

tropous; embryo minute, in hard fleshy perisperm.—Illustrative Genera: *Smilax*, L.; *Paris*, L.; *Trillium*, Mill.; *Medeola*, Gronov.

Affinities, &c.—The plants are not separated by any good characters from the Asparageous tribe of the Liliaceæ on the one hand, while they pass into Dioscoreaceæ on the other, from which they differ chiefly in having a superior ovary. *Smilax* represents Smilaceæ proper; *Paris*, *Trillium*, &c. have the calyx unlike the corolla, and are sometimes made a separate Order, called Trilliaceæ.

Distribution.—A considerable Order in point of numbers. Temperate parts of Europe, Asia, and America. Many species of *Smilax* in tropical America and Asia.

Qualities and Uses.—*Smilax* has diuretic and demulcent properties, for which the creeping rhizomes of many species are used, under the name of *Sarsaparilla*, as *Sm. medica* (Vera Cruz), *S. Purhampuy* (Peru), *S. syphilitica* (Brazilian), *S. officinalis* (Jamaica), *S. glycyphylla* (Australia); *Smilax aspera* and *excelsa*, natives of S. Europe, have similar properties. *Smilax China* has a fleshy root, said to possess similar properties. *S. Pseudo-China* is largely used in domestic medicine in the United States. *Paris*, *Trillium*, and *Medeola* are more allied to the active Liliaceæ in their properties. *Paris quadrifolia*, a curious herb growing in groves in this country, is said to be a narcotic and poison; *Medeola virginica* is emetic and diuretic. The species of *Trillium* are violent emetics. *Ruscus* has curiously flattened branches, from the surface of which the flowers proceed.

LILIACEÆ. LILIES.

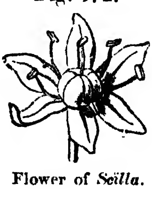
Coh. Liliales, *Benth. et Hook.*

Diagnosis.—Herbs with parallel-veined, sessile or sheathing leaves, regular perfect 6- (rarely 4-)androus flowers, with the petaloid 6-merous perianth free from the 2–3-celled ovary: anthers introrse, attached by a point; style single; perisperm fleshy.

Character.

Perianth free, of 6 pieces in 2 circles (fig. 472), distinct or united, mostly of similar colour, and regular. *Stamens* 6, introrse, springing from the segments of the perianth. *Ovary* free, 3-celled; with numerous anatropous or amphitropous ovules on axile placentas; *styles* simple: *stigma* 3-lobed or undivided, sometimes sessile. *Fruit* dry and capsular, loculicidally valvate, or succulent and indehiscent; *seeds* with the embryo mostly in the axis of fleshy perisperm.

Fig. 472.



Flower of *Scilla*.

ILLUSTRATIVE GENERA.

Tribe 1. LILIEÆ. *Anthers introrse; styles united; fruit capsular, loculicidal.* Tulipa, *L.*; Lilium, *L.*; Hyacinthus, *L.*; Scilla, *L.*

Tribe 2. COLCHICEÆ. *Anthers extrorse; styles separate; fruit capsular, septicidal.* Melanthium, *L.*; Colchicum, *L.*; Veratrum, *L.*

Tribe 3. ASPARAGEÆ. *Fruit baccate.* Dracæna, *Vand.*; Convallaria, *L.*; Aspidistra, *R. Br.*; Asparagus, *Ker*; Ruscus, *Tournef.*

Affinities, &c.—The floral formula is P 3+3 A 3+3 $\overset{\frown}{G\,3}$. The position of the parts may be thus represented:—P ∵+∴ A ∵+∴ G ∵, the typical Monocotyledonous arrangement, but subject to variation according to the position of the bracteoles and other circumstances.

The great Order of Liliaceæ has, by Mr. Baker, been divided into three tribes as above. Smilaceæ closely resemble the Asparageæ, but all Liliaceæ have anatropous ovules, and other marks of distinction are cited under that Order. As aberrant forms of Liliaceæ may be mentioned Liriopeæ or Ophiopogoneæ, Conanthereæ, connecting Liliaceæ proper and Amaryllidaceæ, Gilliesieæ (see p. 388), Stemoneæ or Roxburghiaceæ (see p. 383), and Scoliopeæ. Looking only at the more familiar forms of the Liliaceæ, the characters of the flowers are very definite, although the habit of the plants brought together in this Order varies extremely; but there exist certain genera of petaloid Monocotyledons, whose relations appear closest to Liliaceæ, which form links of chains leading off in very varied directions, through the Orders of this Subclass. *Tulipa* and the allied genera, with usually distinct lobes to the perianth and versatile anthers, are bulbous herbs; *Funkia*, *Hemerocallis*, and other genera have a more or less tubular perianth, and often tuberous roots instead of bulbs; *Aloe* has thick succulent leaves on a perennial stem; *Yucca* has a Palm-like stem and rigid leaves. *Scilla*, *Allium*, and their allies are bulbous herbs, differing chiefly from the group to which *Tulipa* belongs in the firmly fixed anthers, and a membranous spathe enclosing the inflorescence when young. *Anthericum* and others resemble the last, but have tuberous or fibrous roots; *Aphyllanthes* is a plant with the habit of Juncaceæ and the flower of Liliaceæ; *Xanthorrhœa*, a genus belonging to the same group, forms a woody trunk like *Yucca*, or a small Palm. *Asparagus* and its allies, including *Convallaria*, *Smilacina*, *Ruscus*, &c., together with the arborescent *Dracænæ* and *Cordylines*, are Liliaceæ with succulent fruits, and scarcely separable from Smilaceæ. *Conanthera* and its allies, with the general structure of Liliaceæ, have the perianth more or less adherent, thus approaching Amaryllidaceæ. *Wachendorfia*, *Lopholia*, and others have the free ovary of Liliaceæ, but triandrous flowers and the foliage of Hæmodoraceæ. *Aspidistra* bears some resemblance in its foliage to Zingiberaceæ, while the character of the flowers approaches that of the complete Araceæ. *Ophiopogon* and *Peliosanthes* are likewise doubtfully placed here; but their structure is not satisfactorily made out.

We see, therefore, that the Liliaceæ have widely spreading relations, although the typical forms are at once distinguishable. The superior ovary separates them from Amaryllidaceæ. Their very near connexion with Smilaceæ is noticed above; they have a more distant affinity to the Palms and to the Juncaceæ in the general structure of the flowers, differing from both in habit, fruits, and seeds. Gilliesiaceæ and Pontederaceæ are scarcely more than aberrant Liliaceæ with irregular flowers.

The structure of the arborescent stems of *Dracæna*, *Cordyline*, *Xanthorrhœa*, *Yucca*, &c. has attracted considerable attention, since, contrary to the usual habit of Monocotyledons, their trunks sometimes increase

more or less in thickness with age. However, the central axis corresponds essentially to that of the Palms; only a peculiar rind or false bark exists, capable of increase by layers, somewhat in the same way as the liber of Dicotyledons.

Distribution.—A large Order, the members of which are very variously and widely distributed; the bulbous kinds common in temperate climates, the fibrous-rooted with them and in warmer localities: the succulent-leaved *Aloes* chiefly S.-African; the arborescent forms mostly subtropical.

Qualities and Uses.—Many of the Liliaceæ have active properties, and the juices, the fibres, or the fruits afford products of value in the arts. The juice of the succulent-leaved *Aloes* dries into a kind of resin, medicinal Aloes, one of the most valuable of purgatives; the species from which it is usually obtained are *Aloe spicata, vulgaris, socotrina*, &c. The bulb of *Urginea maritima* is the Medicinal Squill, valuable as an expectorant and diuretic, but emetic and purgative in large doses. *Pancratium* (often cultivated for its flowers) has similar properties. The leaves and roots of *Erythronium* (Dog's-tooth), of the Hyacinths (*Hyacinthus orientalis, lusitanicus, Scilla nutans*), and the genera *Muscari, Ornithogalum, Gagea*, all have emetic qualities; the tuberous fibrous roots of *Asparagus* and of the Lily of the Valley (*Convallaria majalis*) are said to be purgative: those of Solomon's Seal (*Convallaria Polygonatum*) are acrid. The bulbs of the Crown-imperial (*Fritillaria imperialis*) and other species, and of *Gloriosa superba*, are said to be very poisonous. The bulbs of the genus *Allium* have milder properties, and at the same time possess a pungent quality, on account of which they are extensively grown for food, the large and milder cultivated kinds being esculent vegetables; the smaller and more pungent are valued for imparting flavour. *Allium Cepa* is the Onion; *A. Porrum*, the Leek; *A. sativum*, Garlic; *A. Schœnoprasum*, the Chive; *A. ascalonicum*, the Shallot; *A. Scorodoprasum*, the Rocambole: "Spanish Onions," coming from Spain, Portugal, and Egypt, are mild varieties of the common Onion, the bulb growing to a larger size, and forming less of the pungent secretion. The bulbs of *Lilium pomponium* constitute an important article of food in Kamtschatka; the tubers of *Camassia esculenta* are eaten by the North-American Indians. The woody roots of *Dracæna terminalis* (*Cordyline Ti*) are eaten, roasted, by the Sandwich-Islanders; sugar and fermented liquor are likewise prepared from its juice; its leaves furnish fodder for cattle, as do those of the Grass-tree (*Xanthorrhœa*) in Australia; the bases of the young leaves and the heart of the buds of the latter are sometimes used as esculent vegetables. The table Asparagus consists of the very young annual shoots (*turiones*) of *Asparagus officinalis*, rendered succulent by cultivation. Astringent resins are obtained from some kinds: *Dracæna Draco*, the Dragon-tree of Teneriffe, yields the true Dragon's Blood, formerly much used in medicine, but now seldom met with, the resin of *Pterocarpus* (Leguminosæ) being substituted. *Xanthorrhœa arborea* yields Botany-Bay Gum, which is yellow, pungent, and smells like Benzoin when burnt. *Phormium tenax* is the New-Zealand Flax plant; the fibre of the leaves is very tenacious, as is that of various species of *Sanseviera*, known as African Hemp and Bowstring Hemp in Africa and the East Indies. Active properties and uses are attributed to many other less-known species. A great number of Liliaceæ, hardy and tender, ornament our gardens and stoves, as will be recognized from the list given above. *Polianthes*

tuberosa is the Tuberose, celebrated for its fragrance. The Butcher's Broom (*Ruscus aculeatus*) is remarkable for its foliaceous peduncles and really almost leafless stems; and the fully developed flowering-stem of *Asparagus* has only needle-shaped branches simulating leaves.

More or less poisonous qualities pervade the Colchicum tribe (Melanthaceæ of some authors), with acrid, purgative, emetic, and sometimes narcotic action; several of the more active species yield valuable medicines. Of *Colchicum autumnale*, called Meadow Saffron or Autumn Crocus, both the corms and seeds are very active; *Veratrum album*, White Hellebore, *V. nigrum*, *V. Sabadilla*, *V. viride* (N. America), *Asagræa officinalis* (Sabadilla or Cevadilla of Mexico), all share the acrid narcotic qualities, poisonous or medicinal, according to the dose. Most of the other genera are suspicious or dangerous, except perhaps the *Uvalarieæ* (N. America), which are said to be merely astringent.

XYRIDACEÆ are sedge-like herbs with equitant leaves sheathing the base of a naked scape, which is terminated by a head of perfect 3-androus flowers, with a glumaceous calyx, a regular corolla, and extrorse anthers: the 3-valved, mostly 1-celled capsule containing several or many orthotropous seeds, with a minute embryo at the apex of fleshy perisperm.—In habit these plants approach Cyperaceæ; but the flowers are petaloid as regards the inner circle of organs, or corolla, nearly approaching Commelynaceæ, from which they differ in having epipetalous extrorse stamens, in the scaly calyx, and general habit. They are natives of the tropics or adjoining regions. Various species of *Xyris* are used as remedies for cutaneous affections both in India and America.

COMMELYNACEÆ (SPIDER-WORTS) are herbs with fibrous, sometimes thickened roots, jointed and often branching leafy stems, and chiefly perfect and 6-androus, often irregular flowers, with the perianth free from the 2–3-celled ovary, and having a distinct green calyx and a coloured corolla, each of 3 parts, the calyx persistent; stamens 6, all fertile or some abortive, often very peculiar in form; capsule 2–3-celled; seeds few (2) in a cell, attached by a linear hilum; embryo pulley-shaped, remote from the hilum, in dense fleshy perisperm.—Illustrative Genera: *Commelyna*, Dill., *Tradescantia*, L.

Affinities, &c.—This Order, to which belongs the garden Spider-wort (*Tradescantia virginica*), may be regarded as one of the groups intermediate between the Orders with 6-merous glumoid perianth, like the Juncaceæ, and the petaloid forms like Liliaceæ. The jointed solid stems of *Tradescantia* are interesting in regard to the comparative structure of Monocotyledonous stems; they emit roots freely from the nodes like Grasses. The hairs of the filaments of the stamens of *T. virginica* are classic objects to the botanist, from the discovery in them of the rotation of the cell-sap in non-aquatic plants. The rhizomes of *Commelyna cœlestis, tubea*, and others contain starch and mucilage, and are used as food in India. Some of the species are said to have medicinal properties. They are natives of India, Australia, Africa, and the West Indies—a few of North America. *Tradescantia virginica* is hardy in our gardens.

PONTEDERACEÆ are a small Order of aquatic herbs with perfect more or less irregular flowers in a spathe; the petaloid, 6-merous

perianth free from the 3-celled ovary; the 3 or 6 mostly unequal or dissimilar stamens inserted in its throat. They are separated from Liliaceæ chiefly by the irregular flowers, the persistent perianth rolling inwards after flowering, and by the mealy perisperm of their seeds.—They are natives of North and South America, India, and Africa, and do not appear to have any important properties. Some of the *Pontederiæ* are usually grown in stoves where there is a tank, on account of their blue flowers.

Mayaceæ consist of four species of *Mayaca*, little Moss-like plants occurring in America, from Brazil to Virginia, separated from Commelynaceæ on account of their habit, 1-celled anthers, 1-celled ovary with parietal placentas, and the carpels opposite the inner lobes (petals) of the perianth. They have no useful properties.

Gilliesiaceæ are a small Order of plants of somewhat anomalous structure, related to Liliaceæ (see p. 385); they are bulbous herbs with spikes of flowers which have a double circle of petaloid envelopes, 6 or 8 subulate processes, then a cup-like or labelloid organ bearing 3 or 6 anthers on its inner surface, and a 3-celled ovary.—Lindley regards the petaloid envelopes and subulate processes all as bracts, and the structure on which the anthers are borne as the perianth. Other authors are opposed to this view. *Gilliesia*, Lindl., and *Miersia*, Lindl., are both Chilian genera.

Philydraceæ are herbs with fibrous roots, ensiform leaves with equitant bases; flowers within a persistent spathaceous bract, with a 3-parted petaloid perianth; 2 upper segments coherent into one; 3 coherent stamens, of which the 2 lateral are barren and petaloid, and the middle has a two-celled anther, the whole adherent to the anterior lobe of the perianth; the pollen-cells are coherent in masses of four; the ovary superior, 3-celled, the odd cell anterior, with axile placentas; seeds numerous, with an embryo in the axis of fleshy perisperm.—This Order consists of two plants, *Philydrum lanuginosum* (Australia) and *Helæria pygmæa* (China), exhibiting, with a superior ovary, appearances analogous to those in the epigynous group of Orchidaceæ and their allies. Lindley regards them as related to Commelynaceæ and Xyridaceæ; but they would appear to be rather a kind of perigynous Zingiberaceæ. They have no known uses.

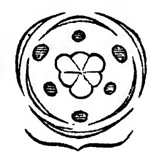
B. Apocarpiæ.

Carpels usually distinct; seed aperispermic.

ALISMACEÆ.

Coh. Potamales, *Hook.*

Fig. 473.



Plan of flower of *Triglochin*: *x*, bract.

is.—Marsh-herbs, mostly with broad petiolate leaves and scape-like flowering stems; flowers perfect or monœcious, with a double perianth, consisting either of a green calyx and a coloured deciduous corolla, or of 2 circles of green scales, each of three pieces (fig. 473); ovaries 3, 6, or numerous, more or less distinct, and separating into as many nuts; seeds campylotropous or anatropous; embryo doubled, hook-shaped, or straight, without perisperm.

ILLUSTRATIVE GENERA.

Subord. 1. JUNCAGINEÆ. *Perianth scaly; anthers always extrorse; ovule inverted; embryo straight.*

Triglochin, *L.*
Scheuchzeria, *L.*

Subord. 2. ALISMEÆ. *Internal circle of the perianth coloured; ovules solitary or twin; ovule and embryo curved.*

Alisma, *Juss.*
Actinocarpus, *R. Br.*
Sagittaria, *L.*

Subord. 3. BUTOMEÆ. *Internal circle of perianth coloured: ovules numerous all over the inner surface of the carpels: embryo curved.*

Butomus, *Tournef.*
Limnocharis, *H. & B.*

Affinities, &c.—The *Alismeæ* bear considerable resemblance to the Dicotyledonous Order Ranunculaceæ, while *Butomeæ* have been compared with the Nymphæaceæ on account of the curious placentation; but there is hardly any real relationship in this latter case. On the other hand, the *Alismeæ* have some similarity to the Commelynaceæ, from which they are separated by the aperispermic seed. This structure of the seed agrees with that of Naiadaceæ, with which this Order is connected by the *Juncagineæ*. *Scheuchzeria* in this last division approaches Juncaceæ.

Distribution.—A small group, the members of which inhabit marshy localities in all parts of the world; most abundant, perhaps, in temperate climates.

Qualities and Uses.—An acrid property is common in the foliage and in the rhizomes, but the latter are sometimes fleshy and farinaceous, and then may be eaten after the acridity is removed by cooking. *Sagittaria sinensis* is cultivated for food in China. Many are very handsome aquatic plants, and are cultivated for the sake of their flowers.

NAIADACEÆ. THE POND-WEED ORDER.

Coh. Potamales, *Hook.*

Diagnosis.—Immersed aquatic plants, with jointed stems and sheathing stipules within the petioles, or with sheathing bases to the leaves; inconspicuous, monœcious, diœcious, or perfect flowers, which are naked or have a free, scale-like perianth; the ovaries solitary or 2–4 and distinct, 1-celled, 1-ovuled; seed aperispermic; embryo straight or curved (fig. 474), with a thin membranous testa. —Illustrative Genera: *Naias*, Willd.; *Zostera*, L.; *Ruppia*, L.; *Zannichellia*, Michel.; *Potamogeton*, L.; *Aponogeton*, Thunb.

Fig. 474.

Embryo of *Potamogeton*, with the testa removed: *a*, radicle; *b*, cotyledon; *c*, plumule.

Affinities, &c.—This Order agrees with Hydrocharidaceæ and Alismaceæ in the structure of its seeds, but differs in the simpler organization of the

inflorescence, which, as also its perianth, is like that of Spadicifloræ, which, however, is connected with that of Alismaceæ in *Scheuchzeria*. Decaisne and Maout, following A. de Jussieu, keep distinct the Juncagineæ, Aponogeteæ, Potameæ, and Naiadeæ, all of which, with the exception of the first, are here included under Naiadaceæ. The groups established or maintained by the authors just cited are collectively characterized by the absence of a perianth or at least of a petaloid perianth, while they are separated one from the other by the form and direction of the embryo, which is straight and slender and with the radicle next the hilum in Juncagineæ, swollen and with the radicle away from the hilum in *Zostera*, swollen and with the embryo so curved that both its extremities are near the hilum in Potameæ, swollen and with the radicle directed to the hilum in Naiadeæ. The form of the stigmas, whether entire and truncate or linear and divided, is also relied on to distinguish the several groups. Some authors consider the inflorescence really spadicifloróus, and regard the scaly perianth, when present, as consisting of bracts surrounding imperfect unisexual flowers; and this idea is supported by the spathe-like bract which occurs in some genera (*Zostera*, &c.). From this point of view they are related to Lemnaceæ; but the character of the seeds is diverse. The structure of these plants is generally very simple, consisting chiefly of cellular tissue of very delicate organization; in *Ouvirandra* the lamina of the full-grown leaf becomes a delicate lattice-like plate, the interspaces between the ribs being destroyed during expansion. *Zostera* is remarkable for its pollen-grains being tubular and destitute of an external coat.

Distribution.—The species are numerous, and are met with in still, fresh and brackish water, and in the sea (*Zostera*), in all parts of the world.

Qualities and Uses.—Apparently destitute of active properties. The leaves of *Zostera marina* are collected and dried on the sea-coast as a material for packing, filling mattresses, &c.

Division II. Spadicifloræ.

Monocotyledons with flowers usually on more or less fleshy, simple or branched spikes (spadices), with or rarely without spathes. Perianth biseriate; segments uniform, herbaceous or none.

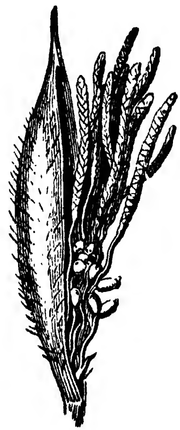
Exceptions, &c.—This group is one readily recognizable, though not easily defined in words. It is subject to many exceptional and transitional forms. In Palms the structure of the perianth is like that of some Liliaceæ or Juncaceæ, but the segments are more fleshy; the Lemnaceæ, usually considered the lowest representatives of the Aroid type, have so few flowers that the spadiciform peduncle does not represent this structure very clearly, but it is surrounded by a spathe. Taccaceæ resemble Araceæ in habit, but their flowers are more complete. The inflorescence is of the same general character throughout, but with many modifications.

PALMACEÆ. PALMS.

Coh. Palmales, *Benth. et Hook.*

Diagnosis.—Trees or shrubs, mostly with a simple unbranched trunk (fig. 478), occasionally slightly ramified, with large terminal clusters of mostly compound, or deeply divided stalked leaves, the stalks sheathing at the base; flowers unisexual or perfect, with a double 3-merous herbaceous perianth, on a mostly branched scaly spadix enclosed by spathe (fig. 475); stamens 6, hypogynous or perigynous; ovary of 1–3 free or coherent carpels; ovules solitary, rarely two; fruit baccate; seeds with a minute embryo imbedded superficially in horny, fleshy, or bony perisperm.—Illustrative Genera: *Chamædorea*, Willd.; *Areca*, L.; *Ceroxylon*, H. & B.; *Caryota*, L.; *Calamus*, L.; *Sagus*, Gærtn.; *Borassus*, L.; *Lodoicea*, Labill.; *Sabal*, Adans.; *Chamærops*, L.; *Rhapis*, L. fil.; *Phœnix*, L.; *Attalea*, H. B. K.; *Elæis*, Jacq.; *Cocos*, L.

Fig. 475.



Spathe and branched spadix of *Astrocaryum vulgare*.

Affinities, &c.—The Palms form a very natural Order, including a great number of plants varying to a considerable extent among themselves, but separated by very distinct characters from the rest of the Monocotyledons. They as a rule, assume an arborescent character, the stem being formed on the same fundamental plan as those occasionally occurring in other Orders of Monocotyledons: the stem of the Calamoid Palms bears much resemblance to that of the Bamboo among the Grasses; the forms with scarcely developed internodes, marked externally by the scars of the fallen leaves, agree essentially with those of *Yucca*, *Xanthorrhœa*, &c., except that the fibrous cortical region is little developed and does not exhibit growth by successive layers as in those plants; the *Hyphænes*, which have a branched stem, seem to ramify in the same way as the *Vellosiæ*, by a bifurcation resulting from the occasional development of an axillary bud, which manifests a power of growth equal, or nearly so, to that of the terminal bud. The ramification of the trunks above ground is a rare phenomenon; but it is very common for suckers to be sent out from the bases of the stems below the soil, imitating on a large scale the appearance of the young bulbs around the parent in the herbaceous Monocotyledons. The parenchymatous substance of the stem, in which the fibrous structures are imbedded, varies much in consistence: sometimes it becomes lignified, and gives a solid character to the trunk, as in the Cocoa-nut Palm; sometimes it is soft and spongy internally, as in the Sago-palms, becoming filled at certain seasons with starch. The spadiciform inflorescence, unfolding from within a large foliaceous spathe, connects the Palms with the Araceæ, a relationship further indicated by

the low type of structure of the floral envelopes; but there is a general tendency to union of the sexes here, and a difference in the position of

Fig. 476.

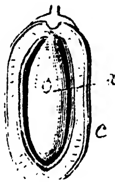


Fig. 477.

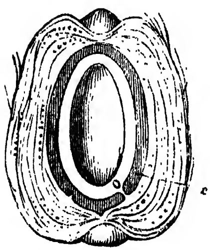


Fig. 478.

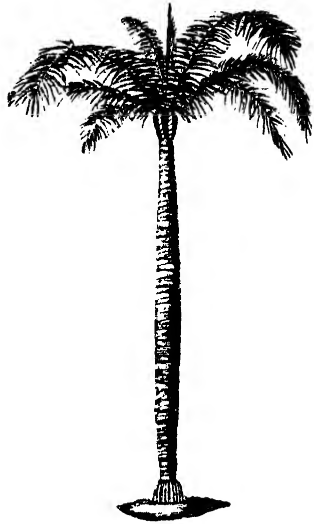


Fig. 476. A Date, with half the pericarp removed (*c*) to show the seed and embryo (*x*).
Fig. 477. Section of the fruit of the Cocoa-nut Palm: *x*, the shell of the nut.
Fig. 478. Trunk and foliage of a species of *Areca*.

the embryo within the perisperm—not to dwell upon the wide diversity of general structure and habit. The regular ternary arrangement of the flowers, the 6 stamens, and the 3-carpellary superior ovary approximate this family to the Liliaceæ, in which, however, the habit differs in almost every respect, besides the great diversity of the fruits and seeds. The floral formula of a perfect Palm flower is thus that of a typical Monocotyledon, but variations occur from suppression of parts and in accordance with the relative position of the bracteoles, &c. The inflorescence of the Palms is in some cases axillary, allowing of indefinite growth of the trunk by the terminal bud; in other cases it is terminal, and the flowering of the plant then puts a period to the term of growth (sometimes as much as 20 years), the trunk dying after the ripening of the fruit (like the main stem of the *Agave*), but occasionally perpetuating itself by subterranean axillary suckers. Sometimes the axillary inflorescence breaks out from above the cicatrix of a long-fallen leaf, on the bare part of the stem. The flowers are generally very numerous; it is said that the male inflorescence of the Date may bear 12,000 flowers, and that a bunch of some of the South-American Palms will bear 3000 fruits. In *Alfonsia amygdalina* 207,000 flowers have been computed on a single spadix, or 600,000 on one plant! There is very considerable apparent variety of form and structure

of the ripe fruit in this Order, easily reducible, however, to a single type. As a rule, there are 3 carpels, either distinct or united into a 3-celled ovary, each carpel commonly producing 1 ovule; in *Cocos*, however, 2 out of the 3 cells are rudimentary, and thus only one ovule is developed even at first; in *Areca* and others, 3 distinct cells and ovules originally exist; in *Chamærops* and *Phœnix* the 3 carpels form separate 1-ovuled pistils; in *Borassus*, a 3-celled, 3-ovuled ovary exists, and the same in *Lodoicea*. In the course of the maturation of the fruit, the pericarp becomes variously developed, and more or less of the ovules or of the distinct simple ovaries are aborted. In *Cocos* the pericarp is developed around the one perfect cell, externally as fibrous husk, internally as the woody shell of the nut; the fleshy part of the nut (hollow) constitutes the albumen of the seed surrounded by a brown testa; and the embryo is lodged in a cavity in the substance of the perisperm, at one side, near the base (fig. 477). In *Areca*, 2 out of the 3 cells and ovules are abortive; the pericarp ripens into a fibrous husk round a solid seed, chiefly composed of horny ruminated perisperm (the Areca-nut). In *Chamærops* and *Phœnix*, 1 out of the 3 simple ovaries ripens into a berry; the pericarp, becoming the pulp (Date), contains a "stone" or seed, which is a solid mass of horny perisperm with the embryo imbedded in a small cavity a little beneath the surface (fig. 476), its place being indicated by a papilla on the surface. In *Borassus*, all the ovules become developed, and form 3 fibrous "stones" in the fruit. In *Lodoicea* it often happens that 2 or even 3 ovules coalesce during ripening, forming large, hollow, double or triple nuts, of the same character as the Cocoa-nut, enclosed in a large fibrous husk (these are the "Double Cocoa-nuts" of the Seychelles Islands). In *Sagus* and other genera the ovary is clothed with imbricated scales pointing to the base, which ripen into woody structures, forming a peculiar hard-scaled covering to the fruit. These scales, according to Spruce, are rudimentary leaf-blades [scales?] reflected.

The subdivisions of the Order depend upon the habit, foliage, nature of the fruit, attachment of the seed, position of the embryo, &c.

Distribution.—A large Order, consisting of about a thousand species, chiefly tropical; scarce as regards species in Africa; a few advancing into temperate latitudes in North America, Europe and Asia, and New Zealand. Remains of Palms have been found in the Upper Cretaceous and more recent rocks.

Qualities and Uses.—Having (apparently) no noxious properties, the very varied products of this noble Order of plants render them of an importance to man second, perhaps, only to that of the Cereal Grasses. Their juices and secretions furnish sugar, starch, oil, wax, and resins; fermentation of the juices of many produces spirituous liquids. Some have edible fruits of great importance; the succulent buds of others are used as esculent vegetables; their leaves are applicable to countless uses, from thatching huts to plaiting mats and hats; the fibrous substance of the sheathing petioles furnishes materials for cordage, or, when more solid, supplies a valuable substitute for bristles and whalebone; the fibrous husks of the fruits afford textile materials; the trunks of some kinds become valuable timber; and the hard perisperm of the seeds of several kinds is very largely used for turners' work connected with cabinet-making &c.

Saccharine juice, furnishing sugar or fermented liquid, according to the

use made of it, is obtained abundantly by cutting the unopened spathes of *Caryota urens*, *Cocos nucifera*, *Borassus flabelliformis*, *Rhapis vinifera*, *Saguerus* (*Arenga*) *saccharifer*, *Phœnix sylvestris*, *Mauritia vinifera*, *Elais guineensis*, and others; starch is obtained abundantly from the central parenchyma of the trunk of *Sagus Rumphii*, *Metroxylon læve*, *Saguerus saccharifer*, *Phœnix farinifera*, &c. Oil is obtained especially from the African Oil-Palms (*Elais guineensis* and *E. melanococca*), the fruits being crushed and the oil extracted from the perisperm by boiling in water; Cocoa-nut oil is obtained from the perisperm of the seed; wax is excreted on the lower surface of the leaves of *Copernicia cerifera*, on the trunk and between the leaves of *Ceroxylon andicola*. *Calamus Draco*, *Hyphæne*, and others have a resinous matter in their juices. The most important fruits are those of the Date (*Phœnix dactylifera*) and the Cocoa-nut (*Cocos nucifera*); the fruit of *Hyphæne thebaica*, the Egyptian Doum-palm, is also eaten; and the seeds of *Arecha Catechu* (Betel-nuts) are very largely used, in the East Indies, for chewing with the leaves of the Betel Pepper. The fruits of some of the Palms are acrid (*Caryota*, *Saguerus*); the acridity, however, is removed by soaking in lime-water, and they are eaten preserved with sugar. The Indian Cabbage-palm, of which the buds are eaten boiled like cabbages, is *Areca oleracea*; *Euterpe montana* is used in the same way. Fibrous substance is derived from the husk of the fruit of the Cocoa-nut (Coir), *Astrocaryum vulgare*, *Attalea funifera*, and others; the bristle-like Piassaba fibres, used for brooms, are from *Leopoldina Piassaba*. The wood of the Cocoa-nut Palms is hard, durable, and handsome (Porcupine-wood); *Borassus flabelliformis* yields what is called Palmyra-wood. Nuts suitable for turning are afforded by the seeds of *Attalea funifera* (Coquilla nuts) and *Phytelephas macrocarpa* (Vegetable Ivory). The resin known as Dragon's blood is yielded by *Calamus Draco*.

Common canes are the stems of *Calamus Scipionum*, *Zalacca rudentum*, &c. Partridge canes, used for walking-sticks, &c., are stems of an unknown Palm. The petioles of *Chamærops humilis* are used for walking-canes in Italy; and the fibre of the leaves of this plant is now coming extensively into use as a substitute for horse-hair. The foregoing is only a brief summary of some of the best-known uses of these plants; similar products and applications are connected with a great number of other species besides those here mentioned. Several species are cultivated, for the grandeur of their foliage, in our stoves; and some, such as *Jubæa spectabilis* and *Chamærops excelsa*, are sufficiently hardy to be grown out of doors in the south of England.

PANDANACEÆ (SCREW-PINES) are trees or shrubs of Palm-like habit, but often dichotomously branched, with the leaves sheathing at the base, imbricated in 3 spiral ranks; flowers numerous, naked or scaly, male and female or polygamous, arranged densely on a simple or generally branched spadix furnished with numerous spathaceous bracts; anthers stalked, 2–4-celled; ovaries mostly grouped, 1-celled, with solitary or numerous ovules on parietal placentas; fruits with a fibrous husk, 1-seeded, arranged in groups, or many-celled berries with many-seeded cells; embryo minute, imbedded at the side near the base of the fleshy perisperm.—Illustrative Genera: Suborder 1. PANDANEÆ. Flowers naked; leaves simple. *Pan-*

danus, L. fil.; *Freycinetia*, Gaud.—Suborder 2. CYCLANTHEÆ. Flowers mostly with a perianth; leaves fan-shaped or pinnate. *Carludovica*, R. & P.; *Nipa*, Rumph., *Cyclanthus*, Poit.

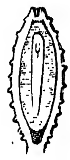
Affinities, &c.—This Order is related on the one hand to the Typhaceæ by the inflorescence, which resembles that of *Sparganium*; on the other to the Palmaceæ, which the *Cyclantheæ* approach in habit and foliage. The branching stem and the large aërial roots of *Pandanus* (fig. 10, p. 19) are exceedingly curious.

Distribution.—Tropical: the *Pandaneæ* chiefly in the East-Indian Islands, Mauritius, &c.; the *Cyclantheæ* American. Fossil Pandanads have been observed in the Upper Chalk. *Nipa* is common in the Eocene deposits of the mouth of the Thames.

Qualities and Uses.—The seeds are edible; saccharine fermentible juice flows from the cut spadices of *Nipa* and other species; the leaves and fibres are used for cordage, plaiting hats, &c.

TYPHACEÆ are marsh-herbs, with nerved and linear sessile leaves and monœcious flowers, on a spadix or in heads, destitute of a proper perianth, which is replaced by 3 or more scales or a tuft of hairs; stamens 1–6, distinct or monadelphous; anthers innate; ovary solitary, 1-celled; ovule solitary, pendulous; embryo in the axis of mealy perisperm (fig. 479); radicle next the hilum.—The habit and general appearance of these plants resemble those of Cyperaceæ, and the hairs of the flowers of *Typha* are analogous to those of *Eriophorum*; but they belong to the Araceous type, and the structure of their inflorescence approaches closely, in *Sparganium* especially, to that of Pandanaceæ, which, however, have the ripe fruits more or less blended into a mass. There is also some resemblance in the inflorescence and in the flowers to Platanaceæ.—The plants grow in ditches and marshes in most parts of the world.—The rhizomes of *Typha* contain a certain amount of starch, and the young shoots of Bulrushes (*T. latifolia* and *T. angustifolia*) are sometimes used as esculent vegetables, like those of Asparagus. The abundant pollen is also nutritious, and is made into a kind of bread in Scinde, in New Zealand, and elsewhere.

Fig. 479.



Section of seed of *Typha*.

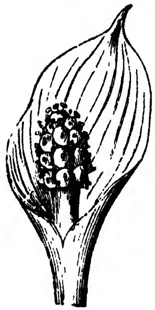
AROIDACEÆ.

Coh. Arales, *Benth. et Hook.*

Diagnosis.—Plants with acrid or pungent juice, simple or compound, often prominently-veined leaves, and monœcious or perfect flowers crowded on a spadix, which is usually surrounded by a large bract or spathe (fig. 480); perianth wanting, or of 4–6 scales; fruit usually a berry; seed with the embryo in the axis of mealy or fleshy perisperm, or occasionally aperispermic.

Fig. 481.

Fig. 480.



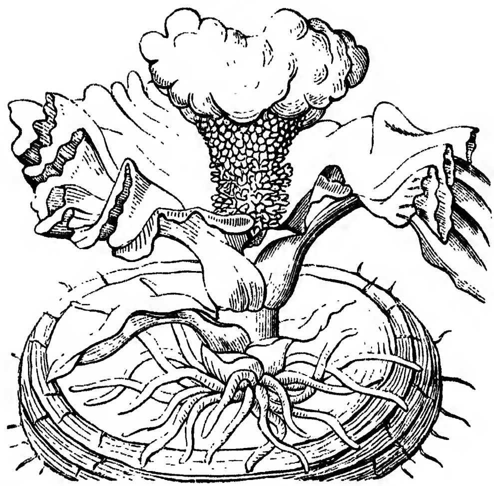


Fig. 480. *Calla*: spathe and spadix.
Fig. 481. *Amorphophallus*: corm, spathe,

ILLUSTRATIVE GENERA.

Subord. 1. ARACEÆ. *Flowers imperfect; spadix surrounded by a spathe.*

- Arum, *L.*
- Colocasia, *Ray.*
- Caladium, *Vent.*
- Dieffenbachia, *Schott.*
- Richardia, *Kunth.*

Subord. 2. ORONTIACEÆ. *Flowers perfect, mostly with a perianth; spadix surrounded by a spathe or naked.*

Tribe 1. *With a spathe.*

- Calla, *L.*
- Pothos, *L.*

Tribe 2. *Without a spathe.*

- Orontium, *L.*
- Acorus, *L.*

By Engler this large group has been recently subdivided into ten suborders and numerous subsidiary tribes and subtribes. The suborders are Pothoideæ, Monsteroideæ, Lasioideæ, Philodendroideæ, Aglaonemoideæ, Colocasioideæ, Staurostigmoideæ, Aroideæ, Pistioideæ, and Lemnoideæ. The principal characters relied on to distinguish these groups are the presence or absence of laticiferous vessels, the presence or absence of H or ⊣ shaped intercellular hairs, the arrangement of the leaves and shoots, the venation of the leaves, the bi- or unisexual flowers, the presence or absence of a perianth, the direction of the ovules, &c. &c.

The floral formula for *Acorus* is P ∵+∴ A ∵+∴ G ∵, the ordinary Monocotyledonous form. In other genera great modifications arise from suppression of parts, &c.

Affinities, &c.—The peculiar thickened fleshy flowering stem densely covered with flowers of rudimentary structure, forming the *spadix* of this

Order, together with the spathe met with in most cases, give the group a character of habit which is generally very distinct; some genera, however, such as *Acorus*, depart from this form, and approach the Typhaceæ or Cyperaceæ in aspect, with which the spadiciflorous structure at the same time unites them; they have further relations with the Pandanaceæ, and also with the Palmaceæ, in which the inflorescence shares the spadiciflorous characters; and although the perianth is much more definite and highly developed there, its presence in *Acorus* and *Orontium* of this Order forms a connecting link. Lemnaceæ are closely related here, and perhaps should be regarded as the simplest form of Aroids; but the conditions are so simple there that it is more convenient to separate them. From Naiadaceæ, in which the inflorescence is moreover hardly spadiciflorous, the Aroids are easily distinguished by the character of their seeds. The Araceæ are either herbs, sometimes with very large leaves and spathes, or their stem becomes more or less developed and branched, so as to give them a shrubby character; while others are epiphytic and climbing plants, producing aërial roots like the Orchids. The leaves are of the most varied character in this Order.

Distribution.—A large Order, not numerous in temperate climates, but represented there by *Arum*, *Calla*, and *Acorus*. Most abundant in the tropics, especially in forests and the lower regions of mountains.

Qualities and Uses.—The juices of the Aroids are generally acrid and dangerous, some very poisonous; but heat seems to dissipate the noxious principles. The acridity is replaced by agreeable aromatic pungency in *Acorus Calamus*. The corms and rhizomes often contain much starch, which is extracted, and purified by washing, from *Arum maculatum* (Portland Arrowroot); while the corms of *Arum indicum*, *Amorphophallus campanulatus*, *Caladium bicolor*, *Colocasia esculenta* ("Cocoes" and "Eddoes," West Indies), *C. macrorhiza* ("Tara," South-Sea Islands), and *C. himalayensis* are eaten, roasted or boiled. The rhizomes of *Calla palustris* are also eaten after thorough washing. *Dieffenbachia seguina*, the "Dumb-cane" of the West Indies, is so called from the inflammation of the tongue and fauces produced by chewing it; *Dracontium pertusum* (remarkable for its perforated leaves) has blistering properties. *Symplocarpus fœtidus*, the "Skunk-cabbage" of North America, is very fœtid, as is also the newly opened inflorescence of *Arum Dracunculus*, *A. italicum*, and others, which produce sickness and serious indisposition in some constitutions. *Richardia africana* is the white spathed "Trumpet-Lily" of our conservatories. The species of *Philodendron* are very handsome stove-plants. *Anthurium Scherzerianum* is particularly noticeable for its brilliant scarlet spathes and its twisted spadix.

LEMNACEÆ are minute stemless plants, floating free on the water, either destitute of distinct stem and foliage, as in *Lemna*, or consisting of tufts of leaves connected by filiform runners (*Pistia*); producing few monœcious flowers, surrounded by a spathe, from a chink at the edge or upper surface of the frond, or in the axils of the leaves; stamens definite, sometimes monadelphous; ovary 1-celled, with 1 or more erect ovules, from the base of the cell; fruit a 1- or more-seeded utricle; embryo straight, in the axis of fleshy perisperm.—*Lemna*, the genus to which the common Duckweeds belong, is one of the simplest representatives of the

Phanerogams, composed of a stem consisting of 2 or 3 small leaf-like lobes producing little filiform roots below, and ultimately displaying a scale-like spathe at the margin, enclosing the inflorescence, reduced to two naked and unisexual flowers; the male flower consisting of one or two stamens, the female of a simple pistil. *Wolffia* is still more simple, inasmuch as it consists of a flat green plate homologous with the thallus of Cryptogams, on which is placed one male flower consisting of a single stamen and one female flower consisting of a single carpel. From the under surface near the edge protrudes a small bud, by which the plant is reproduced vegetatively. It may be thus represented $\underline{\underline{A\,1\,G\,1}}$, the = indicating the thalloid stem. *Pistia*, also represented by little floating water-plants, has distinct tufted leaves, and the tufts are connected by flagelliform branches like the runners of a Strawberry. The spathes are here axillary, and they enclose separate male and female flowers seated on distinct parts of the central line of the spathe, which would appear therefore to be a branch, like the leafy peduncle of *Ruscus*, or else it has the spadix or peduncle adherent to its inner face. By some these genera, with *Ambrosinia*, is included under true Arads. The Lemnaceæ are the lowest forms of the Aroid type of Monocotyledons, and are related by habit to the Naiadaceæ.—The *Lemnæ* occur chiefly in cool climates; *Pistia* principally in the tropics. *Pistia* appears to possess acrid properties; but the plants are of little importance, except, perhaps, as tending to purify the stagnant pools and ditches in which they abound.—Genera: *Lemna*, L.; *Pistia*, L.; *Ambrosinia*, L.

Division III. Glumifloræ.

Monocotyledons with the flowers collected into close spikelets or heads or in loose cymes; perianth glumaceous, biseriate, or none. Leaves sheathing. Seed perispermic.

Exceptions, &c.—The perianth in this group when present is either dry and scaly or bristly—not fleshy or herbaceous. In Juncaceæ, &c., it is quite regular and eucyclic; in Sedges it is often wanting; in Grasses it is scaly and surrounded by glumes. The term "glume" is often used vaguely to signify either a bract or a perianth-segment. It is therefore preferable to use the adjective term glumaceous. The habit is often characteristic; thus we speak of a sedge-like or rush-like habit, implying a rhizome with erect generally unbranched stems, clothed at the base with scaly leaves. Grasses vary much in habit, as described under that Order. Naiads have a glumaceous perianth, but differ in most other particulars from the Orders here associated. Xyrids differ technically in the possession of a true corolla.

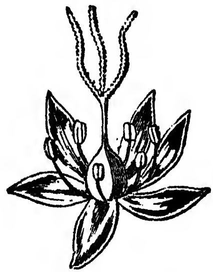
JUNCACEÆ. Rushes.

Coh. Liliales, *Benth. et Hook.*

Diagnosis.—Grass-like or sedgy herbs, with fibrous roots, or a subterraneous rhizome, with jointed stems, often capitate inflores-

cence, and a regular persistent perianth of 6 similar scale-like pieces; stamens 6, or rarely 3, with introrse anthers: ovary 1–3-celled, producing a 3-valved, 3- or many-seeded, or sometimes a 1-celled and, by suppression, 1-seeded capsule: embryo minute, in fleshy horny perisperm; radicle inferior.—Illustrative Genera: *Luzula*, DC.; *Juncus*, DC.; *Narthecium*, Mœhr.

Fig. 482.



Ternary flower of *Luzula*.

Affinities, &c.—With Juncaceæ are included by Lindley a number of genera which are regarded as doubtful, or established as separate Orders by some writers, such as Astelieæ, a group of woolly-leaved epiphytic plants of the southern hemisphere, and Kingieæ, plants with a stem like *Xanthorrhœa* and a 1-seeded fruit, and some others. The genus *Juncus* (Rush) connects the Order to Liliaceæ, from which the chief difference lies in the habit, the small embryo, and the glumaceous character of the segments of both circles of the perianth; *Narthecium* connects them; from Xyridaceæ the latter character divides them. *Xerotes* approaches the Palms in the character of the flowers; and this is associated with *Kingia*, which has an arborescent habit. The scaly perianth connects them with Cyperaceæ, Restiaceæ standing between and differing from Juncaceæ in trifling points, which will be noted under that Order.

Distribution.—A considerable group, the members of which are natives chiefly of cold or temperate regions; some occur in tropical Australia.

Qualities and Uses.—Without important properties in most cases. The leaves of Rushes (species of *Juncus*) are largely used for making mats, chair-bottoms, &c.; and the parenchyma or "pith" of the cylindrical leaves and stems was much used until recently for making the wicks of rushlights; this substance has a beautiful microscopic structure, being formed of regular stelliform cells.

DESVAUXIACEÆ are little sedge-like herbs, with glumaceous flowers in a terminal spathe; glumes 1 or 2; paleæ 0, or represented by scales parallel with the glumes; ovaries usually several, sometimes consolidated, each with a pendulous ovule; stamens 1, or rarely 2; anthers 1-celled; seeds perispermic; embryo terminal.—These little plants, chiefly natives of Australia, are of small importance, except as representing one of the types of the Glumaceous condition of Monocotyledons. They differ from Cyperaceæ in having several 1-celled ovaries more or less coherent, or, if a solitary ovary, it is 1-carpellary; the anthers also are 1-celled, and the embryo terminal, as in Restiaceæ; but they have only one stamen, a 1-celled ovary, and a utricular fruit bursting longitudinally.—Genera: *Centrolepis*, Labill.; *Gaimardia*, Gaudich.

ERIOCAULACEÆ are aquatic or marsh-herbs, stemless or short-stemmed, with a tuft of fibrous roots, and a cluster of linear, often loosely cellular, grass-like leaves, and naked scapes sheathed at the base, bearing

dense heads of monœcious or rarely diœcious, small, 2–3-merous flowers, each in the axil of a scarious bract; the perianth double or rarely simple, scarious; the anthers 2-celled, introrse; the fruit a 2–3-celled, 2–3-seeded capsule; seeds pendulous, winged or hairy, with a lenticular embryo at the end of the perisperm remote from the hilum. The membranous tube surrounding the ovary represents the corolla, and thus places this Order intermediate between the Glumaceous Orders and the Xyridaceæ, which lead on through Commelynaceæ to the Liliaceæ and their allies.—The plants are mostly natives of America and Australia. *Eriocaulon septangulare* occurs in the Western Islands of Scotland (Skye).

RESTIACEÆ are herbs or under-shrubs, generally without perfect leaves: stems usually with slit-convolute leaf-sheaths; with spiked or aggregated glumaceous, mostly unisexual flowers; perianth-segments glumaceous, 2–6, or seldom 0; stamens 2–3, adherent to the inner perianth-segments; anthers usually 1-celled, rarely 2-celled; ovary superior, 1–3-celled, odd cell anterior, ∴; ovule solitary in each cell, pendulous; seeds perispermic, embryo terminal.—Principally distinguished from Cyperaceæ by the pendulous seed and terminal lenticular embryo, further also by the leaf-sheaths being slit; from the Juncaceæ by the same characters, by the stamens, when 3, being opposite the inner glumes, and by the usually 1-celled anthers. They are without the membranous perianth between the glumes and the ovary which occurs in Eriocaulaceæ; while Xyridaceæ, among the Petaloideæ, have the floral envelopes in 2 circles, of which the inner is petaloid. From Desvauxiaceæ they differ in having 2 or 3 stamens, and if with a 1-celled ovary usually 2 styles, and the distinct perianth. In *Lepyrodia hermaphrodita* the flower has six stamens, and the arrangement is typically Monocotyledonous, the odd cell of the ovary anterior.—The species occur chiefly in Australia and South Africa; one occurs in Chili. The tough wiry stems have economic uses, for basket-making, thatching, &c. Genera: *Restio*, L.; *Thamnochortus*, Berg.; *Lamprocaulos*, Mast.; *Willdenovia*, L.

CYPERACEÆ. Sedges.

Coh. Glumales, *Benth. et Hook.*

Diagnosis.—Grass-like or rush-like herbs, with fibrous roots and solid stems, closed tubular leaf-sheaths, without ligules, and spiked perfect or unisexual flowers, one in the axil of each of the glumaceous imbricated bracts, destitute of any envelopes or with a tubular bract (figs. 484 & 485), or with hypogynous bristles or scales in its place (fig. 483); stamens definite, hypogynous, 1–7 or 10 or 12; anthers 2-celled; the 1-celled ovary with a single erect anatropous ovule forming in fruit a utriculus containing a seed with a lenticular embryo enclosed in the base of perisperm.

Illustrative Genera.

Carex, *Mich.*	Isolepis, *R. Br.*	Eriophorum, *L.*
Kobresia, *Willd.*	Scirpus, *L.*	Cyperus, *L.*
Schœnus, *L.*	Eleocharis, *R. Br*	Papyrus, *Willd.*
Cladium, *R. Br.*		

Fig.484

Fig. 483.

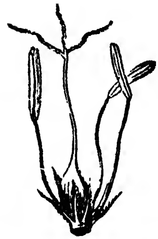


Fig. 485

Fig. 483. Flower of *Eriophorum*. Fig. 484. Female flower of *Carex*.
Fig. 485. Section of the same, showing the ovary.

Affinities, &c.—This large Order of Glumaceous plants resembles in many respects the Grasses, but has several marked distinctive characters, viz. the tubular leaf-sheaths, the usually angular and solid stems, the general reduction of the floral envelopes to a single bract or glume (2 additional glumes exist in *Carex* and some other genera, and hypogynous bristles or setæ in *Scirpus*, *Eriophorum*, &c.), and the fact of the embryo being enclosed centrally in the base of the perisperm of the seed. From Restiaceæ, some of which resemble Sedges in habit, they are distinguished by the erect seeds, by the 1-celled ovary being formed of 2 or 3 carpels, and by the leaf-sheaths not being slit. The floral formula for the male flower of *Carex* is $\underbrace{A}\cdot\!\cdot\!\cdot$, for the female flower $\overbrace{\underbrace{G}}\cdot\!\cdot\!\cdot$, the brackets indicating the bracts. *Cladium* has a succulent fruit. The subdivisions of the Order depend on the distichous or imbricated bracts (glumes), general or partial fertility, open or closed utricle, degree of development of perianth after flowering, presence or absence of staminodes, form of base of style, nature of fruit, &c. The tubular bract of *Carex*, sometimes called the "utricle" (an objectionable term as it may be confused with the form of fruit so named), is, according to McNab and Dyer, a foliar organ, single, or perhaps of two congenitally united, in whose axil the flower is produced.

Distribution.—Universally diffused, especially in marshes and about running streams. *Carex* and *Scirpus* belong chiefly to cool climates, *Cyperus*, *Mariscus*, and others to warmer, while some appear ubiquitous. *Scirpus triqueter* is found in Europe, South America, and Australia. In a fossil state they are first recognized in the Lower Miocene.

Qualities and Uses.—The plants of this Order are generally devoid of active properties, and are less nutritious than the Grasses; but some have bitter and astringent properties, while others are regarded as diaphoretics. Several of them have some economic value. The rhizomes of *Cyperus longus* are astringent, those of *C. rotundus* contain an aromatic oil; the creeping stems of *Carex hirta*, *arenaria*, and other species have been used as substitutes for Sarsaparilla. The rhizomes of *Cyperus esculentus*, *C. bulbosus*, and some other plants of this Order, being tuberous and devoid of noxious properties, are used locally as articles of food. *Papyrus antiquorum*, a tall Sedge, with a spongy pith, is celebrated as having furnished

the ancients with a kind of paper, made by cutting the pith into laminæ, which were laid one upon another and pressed, thereby becoming glued together by their own sap. Its stem was, and is still, used for basket-making, mats, &c., like various *Scirpi* &c. The species of *Eriophorum*, the Cotton-grasses of our moorlands, produce a flock of cottony hairs around the fruit, sometimes used for stuffing cushions, &c. *Carex arenaria* (fig. 25, p. 31) and *C. incurva*, growing on sandy sea-shores, are very efficient in binding the shifting sand.

GRAMINACEÆ. Grasses.

Coh. Glumales, *Benth. et Hook.*

Diagnosis.—Monocotyledons (mostly herbaceous, rarely woody and arborescent), usually with hollow stems, with solid joints at the nodes; leaves alternate, distichous, with tubular sheaths slit down on the side opposite the blade, and a ligule (p. 52, figs. 59, 60) at the base of the blade; the fruit grooved on one side, embryo outside the perisperm.

Fig. 487.

Fig. 486.

Fig. 488.

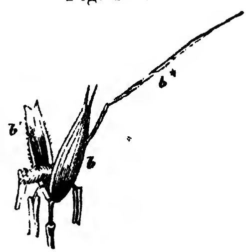


Fig. 486. Spikelet of *Avena*: *a*, *a*, glumes; *b*, *b*, flowering glumes or outer paleæ of florets.
Fig. 487. Compound spike, with spikelets, of *Lolium*.
Fig. 488. Floret of *Avena*: *b*, flowering glume; *b**, awn; *b'*, palea.

Character.

Inflorescence spicate, the flowers arranged in spikelets or *locustæ*, which are again aggregated in spikes, racemes, or panicles; perfect, or sometimes monœcious or polygamous. *Spikelets* mostly with two alternate and unequal dry scaly bracts, called *glumes*,

forming a common involucre enclosing the florets (fig. 486) the outer glume sometimes absent. *Flowers* 2 or many, or rarely solitary with abortive rudiments of others, alternate on the rachis within the glumes, more or less overlapping from below, and each enclosed within the axil of a flowering glume (or outer palea, fig. 486, *b*), which is a bract often provided with an awn, and the palea (inner palea, fig. 488, *b'*) which is two-nerved: the *perianth* is represented by 2 or 3 hypogynous scales (*lodiculæ*, fig. 489, *x*, *x*) sometimes wanting; if 2 in number, collateral, if

Fig. 489.

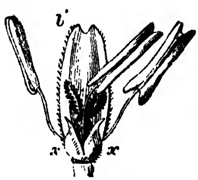


Fig. 490.

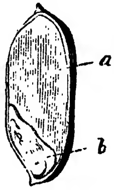


Fig. 491.

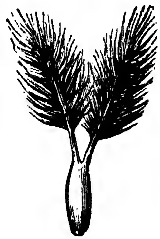


Fig. 492

Fig. 489. Floret of *Avena* with flowering glume removed: *b*, palea; *x*, *x*, lodicule.
Fig. 490. Section of caryopsis of *Triticum*: *a*, endosperm; *b*, embryo.
Fig. 491. Pistil of a Grass, with feathery stigmas.
Fig. 492. Section of embryo of *Avena*, the endosperm removed: *a*, radicle; *b*, cotyledon; *c*, plumule.

3, the odd one posterior, distinct or united. *Stamens* hypogynous, 1–4, or 6 or more (usually 3, the odd one anterior), 1 opposite the flowering glume (alternate with the 2 scales); filaments capillary; *anthers* versatile. *Ovary* superior, 1-celled, with one ascending ovule; *styles* 2 or 3, rarely confluent; *stigmas* feathery or hairy (fig. 491). *Fruit* a caryopsis, with an inseparable pericarp; embryo lying on one side, at the base of farinaceous perisperm (figs. 490, 492).

ILLUSTRATIVE GENERA.

Tribe 1. PANICEÆ. *Spikelets articulated closely below the lowest glume, 2-, very rarely 3-flowered; upper glume always containing the most perfect and only fertile flower; axis of spikelet never produced beyond the flowering glume; lodicles never more than 2.*

Panicum, *L.*
Setaria, *L.*
Sorghum, *Pers.*
Andropogon, *L.*
Coix, *L.*

Tribe 2. PHALARIDEÆ. *Spikelets articulated, sometimes as in* Paniceæ, *and sometimes at the base of the pedicels near the main axis, 3- or apparently 1-flowered; outer empty glumes laterally compressed, often united at the base, longer than the rest: flowering glume terminal, hairy, with 2 rudimentary glumes below it; otherwise as in* Paniceæ.

Phalaris, *L.*

Tribe 3. POACEÆ. *Spikelets usually articulated above the lowest glume, 1- or many-flowered; lowest flower usually perfect, terminal flower very rarely more perfect than those below it; axis of the spikelet almost invariably terminated by an imperfect glume, which is frequently reduced to a small point or bristle; lodicles generally 2, sometimes 3; stamens 1–3, rarely 6; fruit always shorter than the flowering glume.*

Agrostis, *L.*
Stipa, *L.*
Oryza, *L.*
Avena, *L.*
Festuca, *L.*
Bromus, *L.*
Bambusa, *L.*
Hordeum, *L.*
Triticum, *L.*

Affinities, &c.—The tribes above mentioned are those adopted by General Munro, the leading authority on this immense and difficult family. The description of the Grass-inflorescence above given is in accordance with the most modern views of botanists. According to this interpretation, the outer and inner glumes are involucral bracts common to all the flowers of the spikelet, the outer palea or flowering glume is a bract in the axil of which the short axis bearing the flower springs. This short axis bears the inner palea or "Vorblatt," consisting perhaps of two bracteoles united together. The perianth consists of two lodicles placed collaterally, . . ; the andrœcium is made up of 3 stamens, the odd one anterior, ·.·; the gynæcium of two carpels. The entire flower, omitting the bracts and bracteoles, may therefore be thus represented, P . . A ·.· $\overline{\text{G} \cdot\cdot}$. To harmonize this arrangement with that typical of Monocotyledons, viz. P ·.·+.·. A·.·+ .·. G ·.·, it must be assumed that three outer parts of the perianth, one (posterior) part of the inner perianthial row, three stamens of the inner row, and one (anterior) carpel are suppressed. Now in *Streptochata spicata*, according to Döll, the ordinarily missing parts are present, and the Monocotyledonous symmetry is restored, its floral formula being identical with that just given. In Bamboos and in *Stipa* the third lodicle (posterior) is present. In diandrous Grasses (*Anthoxanthum*) the outer stamen is wanting; in most Grasses the inner petal (*lodicula*) is absent. The inner (double) pale is absent in *Alopecurus*, *Panicum*, &c.; in *Lolium* and *Lepturus* the outer glume is absent; in addition to which the few-flowered spikelets of very many genera contain abortive, unisexual, or neutral florets, consisting of rudimentary pales. The comparison of the typical floral structure of Monocotyledons, $\mathrm{P}\,3+3\ \mathrm{A}\,3+3\ \overline{\mathrm{G}\,3}$, with that of Grasses in general may be indicated by placing the numbers referring to the suppressed organs in italics, thus:—$\mathrm{P} + \frac{\mathit{1}}{2} + \mathrm{A}\,3 + \mathit{3}\ \overline{\mathrm{G}\,3}$. By Robert Brown and many others, the flowering glume and the inner palea were looked on as constituting three sepals of a calyx; but the outer palea or flowering glume belongs to a different axis, is inserted lower down, and encircles the floral axis at the base, and the inner palea is a bracteole.

Link looked upon the *lodiculæ* as analogous to the scales in the throat of *Narcissus*, therefore apparently as representing the *ligules* of metamorphosed Grass-leaves. The remarkable awn which is produced on the flowering glume of many Grasses, more or less free from its lamina, is regarded by some authors as a barren development of the axis of the spikelet, which would make the inner pale the subtending bract of the

flower. And it has been considered that the occasional appearance of a flower on the upper part of the outer pale of monstrous flowers of the Nepal Barley (*Hordeum cœleste*) also indicates this glume to be a bract with an abortive floral axis adherent to it. The outer pale of viviparous Grasses (*i. e.* plants with the spikelets developing tufts of leaves) often appears as a rudimentary leaf with ligular processes at the junction of the vaginal and laminar regions, and thus as a simple leaf.

The ligule has been considered an adnate stipule or pair of connate stipules; it seems more simple to regard it as an excrescence from the upper part of the sheathing petiole. The cotyledon of Grasses is usually rather thick and applied to the perisperm. Many other explanations have been given, but this is the simplest and most in accordance with structure and analogy. In *Coix* and some other Grasses, some portions of the spikelet or of the flower assume a bony character; at other times, as in some of the Bamboos, the parts of the flowers become succulent and berry-like. In *Streptochæta spicata* and in *Anomochloa marantoidea* the flower is solitary and terminal. In *Anomochloa* the lodicles are replaced by a row of fibrillæ (Döll).

The stems of *Bambusa* have the habit even of some Palmaceæ, while the structure of the seed approaches that of Araceæ. But the nearest allies, in both habit and structure, are of course the Cyperaceæ: one distinctive mark between them, the hollow stem, suffers exception in *Saccharum* and various Grasses of hot climates; the creeping rhizomes of ordinary Grasses are also commonly solid. The supposed diversity of structure of the stem of Grasses from that of other Monocotyledons is imaginary; their culms are simply fistular states of the structure existing in *Tradescantia virginica*, which, like Grass-stems, roots freely at the nodes. The habit of the Grasses familiar to us in Britain is uniformly herbaceous; but *Saccharum* and some southern forms, such as *Arundo Donax*, *Panicum spectabile*, *Festuca flabellata*, &c., attain the dimensions at least of shrubs; and *Bambusa* is arborescent, having a woody stem 50 or 60 feet or more in height.

Distribution.—Constituting one of the largest natural Orders, the Grasses are universally distributed, and in temperate climates appear in vast numbers of individuals, forming the principal mass of the verdure covering the surface of all but utterly barren soil. The great extent of their cultivation is also remarkable, and still more the absence of information as to the native countries of the Grain-grasses, which have been objects of artificial culture from before the memory of man. Rye, Barley, and Oats are the hardier grains; Wheat is the chief grain of temperate and warm temperate climates, being associated in the latter with Maize and Rice, which form the chief grains of the tropics,—Maize more particularly in America, Rice in Asia, and both, locally, in Africa, Rice-growing being dependent upon the possibility of irrigation. Various Millets (*Sorghum*, *Panicum*, &c.) are largely grown in Africa and Asia, and to some extent in South Europe. The Grasses of warmer climates are more tufted and less gregarious in growth, acquire greater stature, are sometimes arborescent, and very frequently present the monœcious or polygamous condition of the flowers. Grasses in a fossil state have been found in the Upper Eocene and subsequent formations.

Qualities and Uses.—The main value of this Order rests upon the seeds

or more properly the fruits, especially of what are called the "Cereal Grains," just referred to, and which in their abundant farinaceous perisperm, capable of great improvement in quantity and quality under cultivation, furnish the principal material for bread in most countries, except where the severe cold forbids their growth, or the fertile soil and favourable climate supply sufficient food with a less laborious agriculture, as in the case of the Plantain, Bread-fruit, and other tropical esculents. The Sugar-Cane is another grass of scarcely less value: and the fodder-Grasses are of immense importance as furnishing food for domestic animals. A few of the Grasses have somewhat active properties.

The principal Corn-plants are:—Wheat, *Triticum vulgare* and many varieties (Spring Wheat is called *T. æstivum*, Autumn Wheat *T. hibernum*); *T. Spelta*, Spelt; *T. compositum*, the Mummy or Egyptian Wheat, has compound spikes; Barley, *Hordeum distichum*, with its varieties *Hordeum vulgare* (Bere or Big) and *H. hexastichum*; Oats, *Avena sativa* and *A. orientalis* (Tartarian Oats); Rye, *Secale cereale*; Maize or Indian Corn, *Zea Mays*; and Rice, *Oryza sativa*.

Among those less generally known are:—several Millets, such as *Setaria germanica* (German Millet); *Setaria italica* ("Kora Kang," East Indies); *Panicum frumentaceum* ("Shamoola," Deccan); *Andropogon Sorghum* ("Durra") and *A. saccharatum* ("Shaloo," East Indies); *Panicum miliaceum* ("Warree," East Indies); *Penicillaria spicata* ("Bajree," East Indies); *Paspalum exile* ("Fundunji," West Africa); *Poa abyssinica* and *Eleusine Tocussa* ("Teff" and "Tocussa," Abyssinia); *Eleusine Coracana* ("Natchnee," Coromandel); *Zizania aquatica*, Canada Rice; *Phalaris canariensis*, Canary seed, &c. &c.

Among the most valuable fodder-Grasses of temperate climates are:—the Rye-grasses, *Lolium perenne*, *italicum*, &c.; *Phleum pratense*, *Festuca pratensis*, *Cynosurus cristatus*, *Anthoxanthum odoratum*, &c. *Panicum spectabile*, a hay-grass of Brazil, grows 6 or 7 feet high; *Anthistiria australis* is the "Kangaroo" Grass of Australia; *Anthistiria ciliata* and *Cynodon Dactylon* are esteemed Indian fodder-grasses; *Tripsacum dactyloides*, Gama-grass, in Mexico; *Gynerium argenteum* is the Pampas-grass; and *Festuca flabelloides*, the Tussac-grass of the Falkland Islands, is said to be very nutritious.

Saccharum officinarum is the Sugar-Cane; *Sorghum saccharatum* and *Gynerium saccharoides* (Brazil) likewise contain much sugar, as does also Maize, before the grain is ripened. Many Grasses are fragrant; the Sweet Vernal-grass of our meadows, *Anthoxanthum odoratum*, is an example, the scent being most powerful in dried grass; *Hierochloë borealis* is another; and this quality is still more strongly developed in some East-Indian species, such as *Andropogon citratum* ("Lemon-grass") and *A. Ivarancusæ*, *A. Calamus-aromaticus*, and *A. muricatum* ("Vetivert"), of which the roots are largely used. This last Grass has stimulating properties; and another species, *A. Nardus*, is called "Ginger-grass," from its pungency. Many others were formerly, or are still locally, esteemed as medicinal, such as:—*Coix lachryma*, the hard grains of which are known by the name of "Job's Tears"; the common Reeds, *Phragmites arundinacea*, *Calamagrostis*, *Arundo Donax*, *Triticum repens*, (Couch Grass or Quitch of farmers), &c. The supposed poisonous property of Darnel (*Lolium temulentum*) is not satisfactorily ascertained.

Among the Grasses useful in manufactures are the Bamboo (*Bambusa arundinacea*), the Reed (*Arundo Phragmites*, *A. Donax*, &c.). Coarse paper has long been made from the Bamboo in India, and recently from various straws in this country. *Lygeum spartum* is the Esparto Grass, much used as a coarse fibrous material, and also in the manufacture of paper. The Sand-grasses, *Elymus arenarius*, *Arundo arenaria*, and similar creeping species, are valuable binding-weeds on shifting sandy shores. Grasses are remarkable for the quantity of silex existing in the epidermis; and in the Bamboo a solid siliceous substance, called Tabasheer, collects in the hollow joints above the nodes. Many species are cultivated for the elegance of their flowers or their foliage, such as *Arundo Donax*, various species of Bambusæ, *Gynerium* (the Pampas Grass), &c.

SUBKINGDOM II. CRYPTOGAMIA, or FLOWERLESS PLANTS*.

GENERAL MORPHOLOGY.

Introductory Remarks.—The division of the Vegetable Kingdom into Phanerogamia and Cryptogamia is based on the mode of reproduction. It has been seen that in the Phanerogamia the plant accomplishes this by the formation of a *seed* of which the essential part is the embryo. In the Cryptogams, though the processes by which it is arrived at differ widely among themselves, it will yet be found that reproduction is bound up invariably with the formation of *spores* destitute of an embryo, and often consisting of simple cells. At the same time there exists throughout the whole Vegetable Kingdom, in Phanerogams and Cryptogams alike, another mode of reproduction called *vegetative*, which is entirely independent of sexuality, and which usually consists in the mere separation of a part of the mother plant.

The Cryptogamia are divided into two great groups characterized by difference in the structure of their vegetative organs. The higher group, called *Cormophyta*, composed of the Ferns and their allies with the Mosses and their allies, resemble the Phanerogams in the possession of an axis or stem bearing leaves. The lower group, or *Thallophyta*, comprising the Algæ, Fungi, and Lichens, presents in its vegetative structure no clearly marked distinction between root, stem, and leaf; the plant is composed of a *thallus*, formed by simple cellular tissue, sometimes in its shape resembling a leaf, sometimes a stem, and sometimes a root. The simplest plants of this class consist of single cells. Although in general the distinction between Cormophyte and Thallophyte is easily recognized, certain families on both sides possess so close an affinity to each other, that no sharp line of demarcation can be drawn between them. A similar difficulty is experienced on the lower frontier—the much disputed borderland between the Animal and Vegetable Kingdoms.

Cormophyta, or Cormophytal Cryptogams.—The Cormophyta, as already mentioned, consist of the Ferns and their allies,

[* The sections relating to the Cryptogamia have been revised and in part rewritten by Mr. George Murray, of the Botanical Department, British Museum. Although, for uniformity's sake, the account of the Cryptogams is given in this place, yet the student will be unable to understand the anatomy and physiology of these plants without having previously mastered the contents of the subsequent sections relating to Anatomy and Physiology.—ED.]

with the Mosses and their allies. These two groups are distinguished from each other by the structure of their tissues. The Ferns and their allies possess a well-developed vascular system, and under the name of *Vascular Cryptogams* are arranged the *Equisetaceæ*, *Filices*, *Lycopodiaceæ*, *Selaginellaceæ*, and *Rhizocarpeæ*. The Mosses and their allies the *Hepaticæ* (forming the class called the *Muscineæ*) possess no true vascular system, though the tissues in the stems of Mosses have the character of vascular bundles of the most rudimentary kind. In neither Mosses nor Hepatics do true roots, in a morphological sense, occur, though they possess organs (root-hairs) which discharge similar functions. In spite of these defects in structure, the Mosses must still be looked upon as standing higher in the scale, from an anatomical point of view, than such Phanerogams as the *Lemnaceæ*, which have neither true stem nor true root.

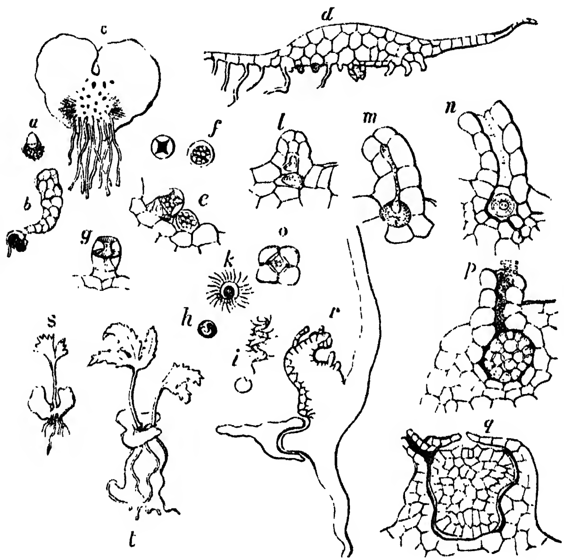
Sexual and Asexual Stages.—In their life-history Vascular Cryptogams pass through two morphologically and physiologically distinct generations—a sexual and an asexual; and this holds true of all Cormophytal Cryptogams. The *spore* is borne in various ways in different families; in the familiar case of Ferns it is borne in capsules or *sporangia* usually on the back of the frond. When it germinates, it produces a thalloid layer of cells called the *prothallium*, and it is on this that the sexual organs are formed. The prothallium contains much chlorophyll, and forms numerous root-hairs. It is soon in a position to nourish itself, and by-and-by produces the male (*antheridia*) and female organs (*archegonia*) (see fig. 493). The antheridia give rise to spermatozoids, which fertilize the archegonia. This is the *sexual generation*.

Out of the archegonium springs the *asexual*, leaf-bearing generation, which, in common language, is usually called a Fern, a Horsetail (*Equisetum*), &c. It bears the spores, as described, and these in their turn again produce the sexual generation (prothallium), and thus the life-history proceeds in alternate sexual and asexual generations. The asexual plants possess a true vascular system, differing in details from that of Phanerogams; and a more special description of their structure will be found under the headings to which they are referred. Their apical growth usually proceeds from a single terminal cell. A remarkable exception to the rule of alternation of generations is found in the reproduction of *Pteris cretica*. Mr. Farlow * discovered that no female organs are formed on the prothallium of this Fern, though the male organs attain full development and produce spermatozoids. The leaf-bearing generation springs from the prothallium in a purely vege-

* "Ueber ungeschlechtliche Keimpflanzen an Farn-Prothallien," Botanische Zeitung, 1874.

tative manner. This important discovery, however, cannot alter our views on the alternation of generation in Vascular Cryptogams,

Fig. 493.



Reproduction of Ferns: *a*, spore germinating; *b*, more advanced (magn. 50 diam.); *c*, full-grown prothallium, with archegonia (lower surface); *d*, vertical section of the central region of a prothallium, passing through an archegonium and two antheridia; *e*, two antheridia (side view); *f*, antheridia seen from above; *g*, antheridium burst (side view); *h*, sperm-cell from antheridium; *i*, spermatozoid escaping from sperm-cell (magn. 300 diam.); *k*, front view of a spermatozoid; *l*, vertical section of a young archegonium; *m*, more advanced; *n*, still older, with the canal open and an embryonal corpuscle in the sac (magn. 100 diam.); *o*, view of the mouth of an archegonium, from above; *p*, vertical section of an archegonium with the embryo in course of development in the sac; *q*, the same, more advanced (less magnified); *r*, vertical section of young plant, more advanced, with a fragment of the prothallium (magn. 50 diam.); *s*, *t*, young plants of *Pteris serrulata*, with their first and second leaves and adventitious roots still connected with their prothallia.

for such an exception cannot, from its abortive nature, destroy the rule.

In the *Muscineæ* the alternation of generations is similar to that in Vascular Cryptogams. Out of the germinating spore (in all Mosses and in some *Hepaticæ*) comes a *Protonema* of a thread-like structure, on which the sexual organs are formed, or (as in most *Hepaticæ*) the sexual generation is directly developed. It is worthy of notice that recently Drs. Pringsheim and Stahl have succeeded in bringing about an artificial production of the *Proto-*

nema, which they caused to spring from certain parts of the asexual plant. This discovery stands in much the same relation to the alternation of generations in the *Muscineæ* as the discovery of Mr. Farlow does to that of Vascular Cryptogams. There are, besides, different modes of vegetative reproduction in Mosses, the principal of which are by *gemmæ* and by *stolons.*

Thallophyta.—We now come to the lower Cryptogams called *Thallophyta*, under which name are comprehended the Algæ, Fungi, and Lichens. The vegetative structure is in the greater number of cases a simple one, since the plant usually consists of a thallus in which no distinction between root, stem, or leaf exists. The class includes organisms, however, of widely different degrees of development. The lowest forms are composed of one cell, and often bear so strong a resemblance to the minute animals called *Infusoria*, that it is only in recent times that a satisfactory division has been established. By almost imperceptible gradations we rise to the highest representatives, in which indications of those forms called leaf and stem appear and an undoubted differentiation of tissues exists. The functions of a root, when such are necessary, are performed by root-hairs, and by a kind of sucker called a *haustorium* in those plants which live by parasitism. The class, from its comprehensive nature, includes an extraordinary number of forms, which can, however, usually be distinguished into a comparatively small number of groups. In their life-history Thallophyta cannot be brought under one general rule, as in the case of the Cormophyta. In many cases a simple alternation of generations is the rule, while in others several generations form a life-cycle, links of which may, under circumstances, be omitted; but this is the exception. In the *Uredineæ*, for instance, three generations form the life-cycle of the plant.

Fungi.—In the Fungi the vegetative body consists, with the exception of several doubtful cases, of filiform, more or less branched *hyphæ* or threads. In many instances the thread is one long, densely ramifying, bladder-like cell; but in most cases it consists of a series of cells placed on end with dichotomous or lateral branches. Of such cells the large bodies of our familiar Fungi, as well as those of the minute species, are composed. The cohesion of the *hyphæ* is usually effected by their being densely interwoven in various ways in the different plants. It must, however, be mentioned that exceptions to this very general condition of things exist. There is found in the stalks of the *Phalloideæ*, in the pileus of *Russula, Lactarius*, in *Sclerotia*, and in the peridia of the *Lycoperdaceæ* a kind of tissue bearing a resemblance to the parenchyme of the higher plants; but this resemblance

is slight, and it has been found necessary to adopt for it the term pseudo-parenchyme. The structure and growth of the fungal cell agree in essential points with those of the vegetable cell as it occurs elsewhere. In the numerous Fungi which develop rapidly and have a short existence in the adult state, the cell-wall is thin, tender, and structureless. The possession of a thick cell-wall of a homogeneous, unstratified nature is not uncommon. Cases also occur (in the *Polyporei*, *Thelephora*, *Bovista*, *Geaster*, *Tulostoma*, &c.) in which, by the aid of sulphuric acid, solution of potash, or of Schultz's mixture, a cell-wall of two or more coats is found, but in certain instances simple immersion in water is sufficient to show a beautiful stratification. From the differences in chemical reaction the cell-membrane of Fungi cannot be called true cellulose, and it has therefore received the special name of *fungal cellulose*. The protoplasm differs from that of the higher plants in the constant absence of chlorophyll and of a nucleus. Drops of oil and other bodies have occasionally been taken for nuclei, by Schacht, for example, who also described nuclei of such infinite minuteness that they could not be accepted. In the formation of vacuoles and the possession of fatty oils, both forms of protoplasm agree. Starch and chlorophyll are always absent, but pigments of various colours occur plentifully. Crystals of calcium oxalate are to be met with in the intercellular spaces of many Fungi, but in only two cases have they been found in the interior of the cell (*Russula adusta* and *Phallus caninus*). Cell-division takes place in the same way as in the other plants.

The reproduction of Fungi is effected by both sexual and asexual means, and the organs by which this is accomplished are in both cases simple cells. No one species is known to possess more than one method of sexual reproduction, though various asexual methods are known to occur in the same species. The organs are called by different names in the different groups, and a description of them will be found under those divisions to which they are peculiar.

Spores.—The term *spore* is used to signify a reproductive body in a general sense, and for the mother cells from which the spores are developed the word *sporangium* is employed. It must be mentioned that, from the very varied modes of reproduction which are met with, a great number of special terms have been proposed in the use of which a certain amount of confusion for some time existed. The spore may be enclosed by one or more coats of different degrees of thickness and density. When it germinates, a tube called a *germ-tube* is emitted, which conducts itself in different ways according to its species. The spore in some instances bursts and produces a number of ciliated spores called *swarm-spores* or *zoospores*, which also behave in different ways. The germination of

the spore is sometimes introduced by division of the spore by septa. The body immediately resulting from germination is called the *mycelium*, and usually ramifies very densely. To it belong the functions of gathering and storing nutriment. From the mycelium there springs the *receptaculum*, on which the reproductive organs are situated. The receptaculum is, *e.g.* in the case of the common Mushroom, that part vulgarly considered the whole body, and it is subject to many variations in shape.

The lowest forms of Fungoid life are to be found in the *Myxomycetes*. In many characters, such as the formation of spores, they agree with the Fungi; but in others they are so far removed that the tendency is to ally them with such animal bodies as *Amœba*. The *plasmodium* (which corresponds to the thallus of the true Fungi) is of a slimy or creamy appearance, and viewed with the microscope it reveals a number of anastomosing, net-like channels which may be compared in function to arteries and veins, and along which there courses an ever-streaming current of protoplasmic matter, bearing such foreign bodies as spores of fungi, starch granules, particles of colouring-matter of different natures, &c. These channels are not confined by a definite membrane, so that a constant changing of position and direction is permitted, and this to such an extent that the plasmodia of different species have been seen to unite. By-and-by a state of rest is attained, and a capsule or sporangium containing spores is formed, which reproduce the organism in a truly fungal manner. Their nourishment takes place in much the same manner as in the case of the animal *Amœba*. To Professor de Bary belongs the honour of having worked out their wonderful life-history.

LICHENS.—Until very recently the Lichens were thought to occupy a position in the Vegetable Kingdom equal in importance to that held by the Fungi and Algæ; but from the more intimate knowledge of their structure and life-history, obtained through the researches of Schwendener, De Bary, Stahl, Bornet, and others, it is necessary now to regard them as only an order of the great group of Fungi called *Ascomycetes*. The thallus and fructification are without doubt identical with those of the *Ascomycetes*; but there enters into the composition of the Lichen another important factor in the form of minute algæ on which the fungal hyphæ lead a life of parasitism. The case may be shortly stated thus:—The green parts of the Lichen, called *gonidia*, are minute algæ, which gather nourishment in a perfectly normal manner. The hyphæ of the fungal parasite extract this nourishment for their own use, and the balance of supply and demand is so preserved that both parasite and host continue to consort through life in a harmonious

manner. The gonidia (algæ) must be looked upon as independent organisms, imprisoned and forced to serve the double purpose of providing for themselves and their parasites. At the same time they reproduce their own species. Their specific identity with members of the genera *Pleurococcus*, *Nostoc*, &c. is well established. The parasites, on the other hand, are true ascomycetous Fungi, reproducing themselves in a strictly ascomycetous manner, and, instead of living on tissues which sooner or later succumb to their demands, have selected hosts offering the greater advantage of persistent life. Of the two components the Fungus is the superior both in bulk and nature, and it is for this reason that the Lichens must be classed as *Ascomycetes*.

ıÆ.—By excluding Lichens, as a Family, the division of the Thallophyta is reduced to that of Fungi and Algæ. The Algæ may be said to form a parallel Family to the Fungi. The same gradation from members which consist of a single cell to higher forms, the thallus of which possesses a structure of a more complicated nature, exists, and the morphological characters rising with equal step present strong marks of similarity with the parallel Family. It has been said that Algæ are Thallophytes containing chlorophyll, and Fungi are Thallophytes in which it is absent; but this classification is arbitrary and otherwise objectionable as based on subjective characters.

The thallus of the higher Algæ resembles that of the higher Fungi. Its histological peculiarities are not markedly different from those of the Fungi. It consists usually of pseudo-parenchyme; and in some instances a seeming differentiation of tissue into epidermis and fundamental tissue is exhibited, though the so-called epidermis must be regarded as only analogous to true epidermis. The cell-walls consist of an unlignified cellulose, which shows a blue colour on the application of iodine and sulphuric acid. Many Algæ are enveloped in a gelatinous substance, which is produced by a process of degradation of the cell-wall. Others again, owing to the deposition of calcium carbonate in the cell-wall or its excretion into the intercellular spaces, attain a calcareous structure, as in *Corallina*. The gelatinous substance serves as a means of fixing the plant to its station, and the calcareous or silicate coats form a valuable protection. It has been stated that the cells possess a nucleus; but this is not well established. Starch occurs frequently, and chlorophyll, sometimes covered by pigments of various colours (which can easily be removed by cold distilled water), is constantly present. The algal cell, from the possession of these substances, stands individually much nearer the ideal perfect vegetable cell than the fungal cell; and the reason is apparent; for, whereas the

algal cell obtains, as a rule, its nourishment in a legitimate, independent way, the fungal cell extracts it after a more or less parasitic manner. A parasitic life, however, is not uncommon among the Algæ. The large Algæ (such as *Fucus*) often attain colossal dimensions and a tree-like form, while the filamentous plants form wavy masses sometimes of considerable length. Those Algæ which consist of single cells sometimes possess the power of motion by fine *ciliæ* (as in the animal *Infusoria*), while sometimes they form colonies cohering by the gelatinous substance just mentioned. The reproduction of Algæ is effected by both sexual and asexual means; and these processes bear often a striking resemblance to those which occur in the Fungi. The asexual means consists usually in the separation of some merely vegetative part from the mother plant and in the detachment of *gemmæ*. In the sexual reproduction a variety of processes obtain which will be described when the families in which they occur are treated of.

The Order CHARACEÆ forms a link of connexion between the Algæ and the Cormophyta, while on the lower frontier such organisms as *Bacteria* unite the lowest plants with the lowest animals.

II. CRYPTOGAMIA, or FLOWERLESS PLANTS.

Plants reproduced by spores destitute of an embryo.

CLASS I. CORMOPHYTA.

Cryptogamous plants usually provided with stems, leaves, and roots, or their morphological equivalents.

Under this head is associated a number of vegetable forms which are closely allied to the Phanerogams in the details of their vegetative structure, but which are separated from them in the processes of their sexual reproduction. Even in their reproduction there is to be observed a degree of similarity with the Gymnosperms (a group of Phanerogams), though this is of so remote a character and so different in the steps by which the point of similarity is reached that near affinity cannot be asserted of them. On the other hand, the vegetative organs are morphologically and physiologically of similar value in Cormophytal Cryptogams and Phanerogams. Just as we have in Phanerogams a scale of degrees in the development of the vegetative body, extending from the morphologically perfect down to the cellular plant, in which leaves, stems, and root are represented by a flat thalloid formation (*Lemnaceæ*), so we have in the Cormophytal Cryptogams a similar scale, in which the degrees are perhaps more strongly marked. In the Cormophytal Cryptogams the *Filices* represent the highest degree in the scale, with stem, root, and leaf perhaps

more highly developed than in any other member of the Vegetable Kingdom. Passing over the less sharply marked degrees in the scale, represented by other Vascular Cryptogams, we come to the Mosses, in which, though stems and leaves are present, we lose sight of the true root, the place of which, however, is supplied by organs of corresponding physiological value. In the stems and leaves, too, we no longer find the relations so perfect, since there is no perfectly organized vascular tissue, but only an indication of it. The anatomical structure of the *Hepaticæ* is comparatively still lower in the scale, and approaches that of the Thallophytes more nearly than any other Cormophyte. The life-history of Cormophytal Cryptogams consists of two distinct generations—a sexual alternating with an asexual one.

Division I. **Vascularia.**

Cormophytal Cryptogams possessing vascular tissue.

The Vascular Cryptogams consist of the *Equisetaceæ*, the *Filices*, the *Lycopodiaceæ*, the *Selaginellaceæ*, and the *Rhizocarpeæ*. Their life-history is composed of two alternating generations—an asexual and a sexual. The asexual generation is that in which the plants are commonly seen and known, and during which they attain the highest point of development in their vegetative structure. They possess in this stage both cellular and vascular tissues, organized in some cases (the *Filices*) on perhaps the most perfect system possessed by any known vegetable. Shortly stated, their life-history begins with the germination of an asexually produced spore, which gives rise to a prothallium (usually a mere layer of simple cells so organized as to sustain an independent life), on which are borne *antheridia* (male organs) or *archegonia* (female organs). The antheridia produce *antherozoids* or *spermatozoids*, as they are differently named, which fertilize the archegonia out of which the asexual spore-bearing generation springs (see fig. 493, p. 410).

The Vascular Cryptogams are divided into five Orders as follows:—

Equisetaceæ.	
Filices.	Spores of one kind.
Lycopodiaceæ.	
Selaginellaceæ.	Spores of two kinds.
Rhizocarpeæ.	

Series 1. Isosporia.

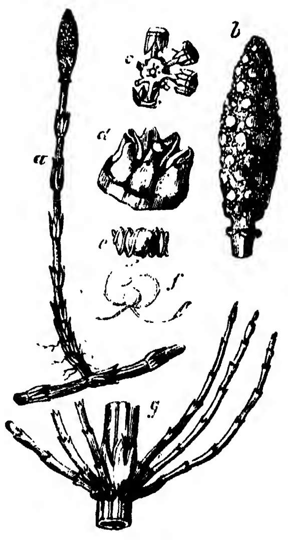
Vascular Cryptogams producing spores of one kind only. Prothallium growing free from the spore and producing antheridia and archegonia.

EQUISETACEÆ. The Horse-tail Order.

Diagnosis.—Asexual Generation: Herbaceous plants with jointed, subterraneous rhizomes, sending up at intervals fistular-jointed

stems, bearing whorls of scale-like leaves at the joints, where they are sometimes verticillately branched. Spores borne on metamorphosed leaf-bearing stems, terminating in a clavate joint covered with dehiscent sporanges. Spores triple-coated, of one kind, with two elastic filaments called *elaters*, formed by the spiral fission of the outer coat of the spore. Stem, rhizome, and root grow longitudinally by means of a single apical cell, giving off three series of segments. Fibro-vascular bundles arranged in a circle. No pericambium in the root. *Sexual Generation*: arising from the spores, consisting of independently subsisting, usually diœcious prothallia, the male prothallia being smaller than the female.—Illustrative Genus: *Equisetum*, L.

Fig. 494.



Organization of Equisetaceæ:—*a*, fertile stem of *Equisetum arvense*, arising from the rhizome; *b*, fruit-spike (nat. size); *c*, transverse section of do., showing how the sporanges are attached to the axis; *d*, a group of sporanges seen from beneath; *e*, a spore; *f*, the same, with its "elaters" uncoiled; *g*, fragment of the branched stem of *E. palustre*.

Structure and Life-history. — The Equisetaceæ at present existing consist of a single genus, *Equisetum*, a small group of herbaceous plants, growing chiefly in wet places, with a creeping, subterraneous, jointed but solid rhizome (fig. 494, *a*), from which arise erect shoots or stems. The stems are striated longitudinally, jointed at intervals, with circles of small and narrow, membranous, scale-like leaves at the nodes, and they are fistular like the stems of Grasses. They are also traversed by several air-canals, varying in number and disposition according to the species. The stems are sometimes simple, sometimes compound, bearing whorls of branches at the nodes, which branches resemble the main stem in character, and frequently branch again in a similar manner at their nodes. The erect stems are either fertile or barren (metamorphosed or true); in some species the fertile stems are short and simple, while the barren stems are tall and provided with numerous whorls of spreading compound branches (*E. fluviatile*). The fertile stems terminate in a kind of club or spike (fig. 494, *b*), composed of a short axis closely covered with *sporanges* (*c*); these are small peltate or mushroom-shaped bodies (*d*) attached by their stalks to the central axis, and bearing under the overhanging head a circle of vertical, tooth-like pouches (*d*), resembling the anther-cells of *Thuja* among Conifers, which burst by a vertical slit on the inside to emit the spores when ripe. The spores

are furnished with filiform processes, called *elaters* (fig. 494, *f*), consisting of two short threads attached at one side, coiled spirally round the spore before it is mature, and unwinding with elasticity when the spore is discharged from the sporange. The erect stems die down annually, while the rhizome persists.

The asexually produced spore of the Equisetaceæ contains a nucleus and chlorophyll granules, and it is, perhaps, owing to this high state of internal organization that its powers of germination are retained for only a few days at the most. The first sign of germination is an enlargement of the spore and the assumption of a pear-like form, during which it divides into two cells; the smaller, possessing almost colourless contents, grows out in the form of a long root-hair, and the other, containing the chlorophyll of the spore, by repeated cell-division ultimately produces the prothallium. The prothallia of the Equisetaceæ are small, flat, thalloid (as their name implies), chlorophyll-containing bodies consisting, in some parts, of several layers of cells, and supplied with irregular arm-like lobes. On the prothallia, which are usually diœcious, are to be found the sexual organs—antheridia or archegonia as the case may be. The male prothallia are usually a few millimetres long, and the female often as much as half an inch; but, although individual in the minor details of form, different species are distinguished by differences in breadth, length, and the nature of their branching. The antheridia, or male organs, are produced at the end of the large and between two smaller secondary lobes of the male prothallia. They contain upwards of 100 large spermatozoids (the largest produced by any Cryptogam), which on being set free swim about in the water, without the presence of which they cannot be emitted. The archegonia, or female organs, arise at the base of the lobes of the female prothallia, and consist each of a few cells so arranged as to form a canal leading to an embryonic cell in the centre of the other cells of the archegonium. The central embryonic cell is fertilized by a spermatozoid through the conductive agency of the canal. Immediately after fertilization the canal cells close, and the embryonic cell begins to increase in size, and the cells of the neighbouring tissue undergo a corresponding increase in number. By-and-by the embryonic cell also divides; and after the division has been often repeated, we begin to see differentiation in the cells, which is the result of this process. The growth proceeds by an apical cell, and a leaf-bearing shoot with a rhizome and root is soon to be seen and recognized as a young *Equisetum* as it is commonly to be found. When the *Equisetum* has attained maturity, the asexual spores (from which we started) are again borne on the erect metamorphosed stem, and so the life-history proceeds in the alternating sexual and asexual generations.

Affinities, &c.—The well-known fossil Calamites resemble in a very striking degree the existing representative of *Equisetum*, not only in the tissues of the vegetative body, but even in the possession of *elaters* in the fructification. The plants of this Order at present existing belong all to a single genus, which is very unlike any other form of Cryptogamous plants. In external appearance the stems have no little resemblance to those of *Ephedra* and *Casuarina*; but their internal organization is totally different. They resemble the Grasses in having a deposit of silex in the epidermal tissues of fistular erect stems, in *E. hyemale* so abundant that the ashes of

the stem form a good polishing-powder, like fine tripoli. In their life-history these plants agree essentially with the Ferns.

Distribution.—The Equisetaceæ are found in wet places in most parts of the globe. Calamites and other plants referable to this group occur in the Carboniferous and other rocks.

FILICES. Ferns.

Diagnosis.—Asexual Generation: Herbs with a subterraneous rhizome, or trees with an unbranched caudex, with well-developed, generally more or less divided or compound leaves, circinate in vernation, and all or part bearing clusters of sporanges (*sori*) upon the lower surface (fig. 495, *a*, *b*, *d*) or at the margins (*g*), seated upon branches of the veins. The *sori* are either naked (*b*) or covered at first by a variously formed dehiscent or separating membranous structure (*indusium*, *d*, *e*) which is continuous with the epidermis of the leaf. The sporangia are metamorphosed hairs, and the leaves which bear them are sometimes also themselves metamorphosed. An apical cell is not always present, but where it occurs it gives off, in the stem, either two or three series, and in the root always three series of segments. The vascular bundles are very strongly developed, and the central xylem, composed chiefly of scalariform, thickened tracheides, is surrounded by weak phloëm. *The Sexual Generation*, arising from the spores, consists of independently subsisting monœcious prothallia.

Illustrative Genera.

Tribe 1. Polypodieæ. *Sporanges stalked, with a vertical annulus.*

Acrostichum, *L.*
e, *Desr.*
Ceterach, *Adans.*
Polypodium, *L.*
Adiantum, *L.*
Pteris, *L.*
Allosorus, *Bernh.*
Blechnum, *L.*
Asplenium, *L.*
Scolopendrium, *Smith.*
Lastræa, *Presl.*
Aspidium, *Swartz.*
Cystopteris, *Bernh.*

Tribe 2. Cyatheæ. *Sporanges sessile, more or less elevated on a common receptacle; annulus vertical.*

Alsophila, *R. Br.*
Cyathea, *Smith.*

Tribe 3. Parkerieæ. *Sporanges thin, with a broad, imperfect, vertical annulus.*

Ceratopteris, *Brongn.*
Parkeria, *Hook.*

Tribe 4. Hymenophylleæ. *Sporanges on an axis produced by the excurrence of a vein beyond the margin of the leaf; annulus horizontal or oblique.*

Hymenophyllum, *Smith.*
Trichomanes, *L.*

Tribe 5.
; commonly arranged in fours in the dorsal sori, nearly sessile, with a transverse or oblique annulus; bursting vertically on the inside.

Gleichenia, *Smith.*
Mertensia, *Willd.*

Tribe 6. SCHIZÆEÆ. *Sporanges dorsal; the annulus in the form of a cap on the summit; dehiscence vertical.*

Schizæa, *Smith.*
Lygodium, *Swartz.*

Tribe 7. OSMUNDEÆ. *Sporanges stalked, dorsal, or arranged on pinnæ assuming a spiked or paniculate aspect from the absence of parenchyma between the veins; annulus incomplete, dorsal; dehiscence across the vertex.*

Osmunda,
Todea, *Willd.*

Tribe 8. MARATTIEÆ. *Sporanges free, closely packed in two rows or in a circle, or soldered together so as to resemble a many-celled capsule, each cell opening by a pore; annulus none.*

Angiopteris, *Hoffm.*
Marattia, *Sm.*
Danæa, *Sm.*

Tribe 9. OPHIOGLOSSEÆ. *Leaves not circinate; sporanges 2-valved, on the sides of a spike or scape, which is simple or branched; annulus none.*

Ophioglossum, *L.*
Botrychium, *Swartz.*

Structure and Life-history.—The Filices or Ferns exhibit a far greater variety of conditions than the Horsetails. Their most remarkable character is the great development of the leaves, the stem being represented in most cases by rhizomes, although in some of the exotic forms it becomes a real trunk, rising above the ground in a manner analogous to the trunks of Palms (fig. 34, p. 38).

The rhizomes of the herbaceous kinds are subterranean, and grow either horizontally or vertically. In the former the internodes are either developed or undeveloped; when they are developed, the leaves arise singly from the ground, as in the common Brake-fern (*Pteris*) and *Polypodium vulgare* (fig. 495, *a*); when the internodes are undeveloped, the leaves are tufted, which is always the case when the rhizome is erect, as in *Athyrium Filix-fœmina*; and the arborescent kinds likewise exhibit the tufted growth of the leaves from a terminal bud, with little development of the internodes. The rhizomatous stems frequently branch, in which case the stem bifurcates, as in the Lycopodiaceæ.

The leaves of the Ferns resemble those of the Phanerogamia in their essential structure; they are very remarkable for their multifold compound forms. The venation or ribbing exhibits a peculiarity, the ramification of the veins in the laminæ being on a bifurcated plan (fig. 495, *b*, *d*), and the subdivisions retaining an equal size. The leaves are also characterized by the circinate vernation (p. 74) which is almost universal in the Order, the only exception being found in the *Ophioglosseæ*.

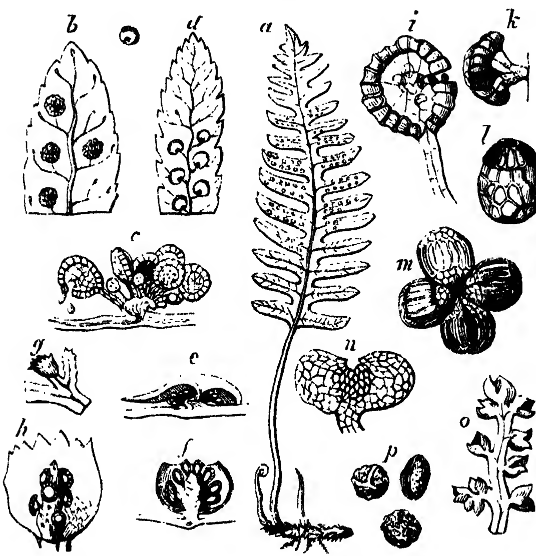
The fructification or sporiferous apparatus of the Ferns is produced upon the leaves; and it presents a great variety of modifications, which serve to characterize the principal subdivisions of the Order. The *spores* are formed in spore-cases or *sporanges*, little membranous sacs attached by a pedicle to the lower surface of the leaf (fig. 495, *b*, *c*, *i*, &c.), or to a kind of skeleton of the leaf in which the parenchyma is suppressed (*o*). These spore-cases differ in some essential particulars of structure, in the mode of attachment, and in their relations to each other.

In most of the Filices the spore-cases possess an *annulus* or ring (fig. 495, *i*), an incomplete ring of thickened cells running round the sac, and assisting, by its contraction when dry, to rupture the sac and set free the spores. In the *Polypodieæ* and other tribes it is vertical (fig. 495, *i*); in the *Hymenophylleæ* the ring is oblique and unconnected with

the basal pedicle (*k*); in the *Gleicheniee* the ring is horizontal (*m*); and in the *Schizææ* it forms a kind of cap with radiating striæ on the top of the spore-case (*l*); in *Osmundeæ* the ring is broad, but imperfectly developed (*n*), while in Marattieæ and Ophioglosseæ (*o*) it is absent altogether.

In most of the tribes the spore-cases are distinct from one another, but collected in groups (*sori*) of various forms, round, linear, &c. (fig. 495, *b*, *c*), on the lower surface of ordinary leaves, or of leaves especially

Fig. 495.



Organization of Ferns:—*a*, plant of *Polypodium vulgare*; *b*, fragment of a pinna with naked *sori*; *c*, vertical section through one of the sori, showing the attachment of the sporanges to the leaf; *d*, portion of a pinnule of *Lastræa Filix-mas*, the sori covered with *indusia*; *e*, vertical section through a sorus of the same, showing the attachment of the indusium and sporanges; *f*, vertical section of a cup shaped indusium and sorus of *Cyathea*; *g*, marginal sorus of *Hymenophyllum*; *h*, the same, with one valve removed, to show the attachment of the sporanges; *i*, sporange of *Polypodium*, bursting; *k*, sporange of *Hymenophyllum*; *l*, sporange of *Schizæa*; *m*, group of sporanges of *Mertensia*; *n*, sporange of *Osmunda*; *o*, portion of the fertile lobe of the frond of *Botrychium Lunaria*, with the sporanges burst; *p*, spores of Ferns.

devoted to the fructification and modified in form and texture. The *sori* are either *naked* (*b*, *c*), or covered by a membranous cover or *indusium* (*d*, *e*), the forms and modes of attachment of which furnish systematic characters. In the Marattieæ the spore-cases are usually more or less coherent together, so as to form a false compound multilocular sporange. Luerssen states that the sporangia of Marattiaceæ originate from a group of cells and not from a single cell (trichome) as in other Ferns. In the

Hymenophylleæ the sporanges are attached to little columns formed by the production of the ribs beyond the margins of the leaves (*g*, *h*), becoming at the same time enclosed in cup-like receptacles formed from the margins of the leaf. In the Ophioglosseæ a portion of the leaf is transformed into a simple or compound spike-like process, covered with free spore-cases destitute of a ring, and splitting regularly to discharge the spores (*o*).

The *spores* are simple cells of microscopic dimensions, furnished, like pollen-grains, with a double coat, the outer of which is generally similarly marked with papillæ, reticulations (*p*), &c.

The term "flowering" fern is erroneously applied to those kinds in which the fertile leaves or lobes are destitute of parenchyma, and thus resemble superficially the spadices of Phanerogamia, as *Osmunda*, *Botrychium*, *Ophioglossum*, &c.

The arborescent Ferns belong to the Polypodieæ and Cyatheæ, and differ only in habit and dimensions from the more familar forms.

Ferns are sometimes reproduced by buds, analogous to bulbils, formed on different parts of their structure, and sometimes at the points of the leaves.

The spores of the Filices retain their germinating power longer, as a rule, than those of the Equisetaceæ. They have usually a granulated appearance, with a cuticularized exospore. On germinating, the exospore bursts, and the contents, already divided into several cells, are protruded, and from it arises the prothallium. The prothallia of Ferns differ from those of the Equisetaceæ in being generally more regular in outline. They produce numerous root-hairs and are self-supporting. The antheridia and archegonia naturally differ, though but slightly, from those of the Equisetaceæ in form, but agree with them entirely in the details of function. The antheridia are situated on the margin or surface, and the archegonia on the surface of the prothallia. They are monœcious, but show in some cases a tendency to be diœcious. After the embryonic cell of the archegonium has been fertilized by a spermatozoid, the asexual generation arises from it in a similar manner to that described as occurring in the Equisetaceæ. An exception to this is to be found in the property of certain prothallia of propagating the asexual generation in a purely vegetative manner. The prothallia of *Pteris cretica* were found by Mr. Farlow to do so without ever having been seen to produce archegonia.

Affinities, &c.—The Filices constitute a very large and natural group of Cryptogamous plants which have no very close relations, as regards general structure; but the *Ophioglosseæ* seem to form a link between *Osmundeæ* and Lycopodiaceæ. As regards the physiological processes occurring in reproduction, this Order must be classed with the Equisetaceæ. There is, however, great diversity of habit in the vegetative body, which, as a whole, may be expressed by saying that the leaf predominates in the Ferns and the stems in the Horsetails.

The *Ophioglosseæ* depart importantly from the general characters, both in their foliage and their reproductive organs; to the form of the latter there is an approach in Marattieæ, and perhaps we may admit that the sporanges of this Order are really like those of Lycopodiaceæ; the development of the young spores appears to agree, however, with that of the Ferns and Equisetaceæ, which is on a totally different plan from that of Lycopodieæ.

The *Marattieæ*, by the absence of the annulus and the grouping of the sporanges, appear to stand between the Polypodieæ and the Ophioglosseæ.

Distribution.—The Ferns at present existing strongly resemble the fossil Ferns, many of which have been preserved, even as to the details of their structure, with wonderful perfection. They were very abundant in the Carboniferous epoch, and traces are also found in the Devonian. The Ferns are universally distributed—more abundantly, however, in damp, mild climates, which favour the development of foliage. The Ferns of temperate climates in the northern hemisphere are herbs; in the islands of the tropics and the south temperate latitudes arborescent forms occur having the habits of Palms. Ophioglosseæ are sparingly represented in Europe and North America, the West Indies, at the Cape, Tasmania, &c., but are most abundant in the Indian islands.

Qualities and Uses.—Some of them have active properties, astringent, anthelmintic, and emetic qualities, &c., but they are of little importance; the rhizomes of *Pteris* &c., and the stock of some arborescent kinds, afford a poor nutriment, used by the aborigines of the South-Sea Islands and elsewhere in times of scarcity. It need scarcely be mentioned that this is the favourite Order of Cryptogamia among cultivators of plants.

LYCOPODIACEÆ. CLUB-MOSSES.

Diagnosis.—Asexual Generation: Herbaceous plants with creeping stems branching in a bifurcating (dichotomous) manner, clothed with small, usually closely imbricate leaves traversed by one simple vascular bundle. The branching of the stem and root is entirely, or in a modified form, dichotomous. The fibro-vascular bundles of the stem contain several xylem-bundles, surrounded and separated from each other by phloëm. Neither stem nor root possess an apical cell. The sporangia arise in the axils or at the base of the leaves, and are larger than those of the Ferns; the capsules are reniform (kidney-shaped), and are placed at the end of short, stout stalks: they contain numerous spores similar to each other in size and form, which is tetrahedral.—*Sexual Generation*: The prothallia arising from the spores are independently subsisting and monœcious.—Illustrative Genera: *Lycopodium*, L.; *Psilotum*, Sw.; *Phylloglossum*, Kze.; *Tmesipteris*, Bernh.

Structure and Life-history.—The Lycopodiaceæ have slender stems (in the genus *Lycopodium* hard and woody), with an erect or creeping habit. The size and form of the leaves differ according to the species. They are always simple, unbranched, sessile with slender bases, and arranged either spirally or in a verticillate manner, but sometimes in both ways on the same plant. Adventitious roots are usually given off at the forks of the stem. The stages in the reproduction of the Lycopodiaceæ are not well known. The germination of the spores of *Lycopodium* has been seen and described only by Professor de Bary, and the prothallia have been found

by Fankhauser with one of them already attached to the young spore-bearing generation. They possess root-hairs, and are self-supporting and monœcious. Antheridia containing numerous spermatozoids are formed abundantly on the upper surface of the prothallium, on which side the archegonia also are situated. Of the phases in the development of the embryo nothing is known.

Affinities, &c.—The immediate relations of this Order are with the Selaginellaceæ.

Distribution.—The species of *Lycopodium* are widely diffused throughout the world, but are most abundant in warm countries. Five species are natives of Britain. *Psilotum* is a native of the tropics of both hemispheres and of Australia. In former ages the species of this Order seem to have attained much greater dimensions than they have at present. The fossil stems known as *Lepidodendron* are like existing Tree Ferns, but their fructification is that of Lycopods. They existed in such abundance in the Carboniferous times that some varieties of coal are stated to be almost entirely composed of their remains. *Lepidostrobus* is the fruiting spike of some Lycopod.

Qualities and Uses.—It is asserted that some kinds of *Lycopodium* are poisonous. *L. clavatum* has been used as an emetic. *L. Selago* and *L. catharticum* are purgatives; the latter is very violent in its action. The powder known in pharmacies as *Lycopodium* consists of the spores of a species of this genus. They are very inflammable, and are hence used for theatrical purposes; and as they no not absorb water readily, they are used for covering the hands &c. when it is desired that they be not wetted.

Series 2. Heterosporia.

Vascular Cryptogams producing spores of two kinds, macrospores and microspores. The macrospores develop a female prothallium, which remains attached to the spore; the microspores produce a rudimentary male prothallium, which remains attached to the spore and develops antheridia and antherozoids.

In the three preceding Orders (Equisetaceæ, Filices, and Lycopodiaceæ) the prothallia arise from spores of one kind. In the two following Orders (Selaginellaceæ and Rhizocarpeæ) the female prothallia are produced by *macrospores*, and the male prothallia by *microspores*. The prothallia are also different in their nature. In the three preceding Orders the prothallium is self-supporting, and possesses completely the character of an independent plant. In the two following Orders the prothallium is no longer an independent plant, since it is formed within the spore, and at no period breaks connexion with it.

SELAGINELLACEÆ.

***Diagnosis.—Asexual Generation*:** In *Selaginella* the stem is thin, dichotomously branched, bearing small heart-shaped appressed

leaves arranged in four nearly vertical rows, and generally of two forms. In *Isoëtes* the stem is perennial and corm-like, having the internodes suppressed. The leaves are spirally arranged in the form of a rosette, broadly inserted. The corm-like stem emits adventitious roots on the underside, but, owing to the dense rosette of leaves, is invisible from above. The leaves are larger than in *Selaginella*, and expanded into a kind of sheath at the base; they are traversed by four longitudinal air-canals. In both *Selaginella* and *Isoëtes* the leaves are simple, unbranched, pointed, and traversed by one vascular bundle. Sporangia, which are placed on the leaves in *Isoëtes*, and on short stalks in their axils or above on the stems in *Selaginella*, produce two kinds of spores—*macrospores* and *microspores*. In *Isoëtes* the macrospores are numerous, in *Selaginella* usually 4, sometimes 2 or 8; in both the microspores are numerous.—*Sexual Generation*: The macrospores produce female, and the microspores male prothallia.—Illustrative Genera: *Isoëtes*, L.; *Selaginella*, Spring.

Structure and Life-history.—In the Selaginellaceæ, as has been said, the microspores produce the male prothallia. The germination of the microspore is effected by its dividing into a few cells, of which one is sterile and the others produce spermatozoids. The macrospores produce the female prothallia by developing within themselves a mass of cells, while the wall of the endospore begins to increase in thickness and separates into layers. Owing to the cell increase within, the exospore bursts, and after some time the wall of the endospore leaves uncovered that part of the prothallium the function of which it is to produce the archegonia. Fertilization by means of the spermatozoids takes place in the manner common to all Vascular Cryptogams, and the asexual generation arises from the embryonic cell.

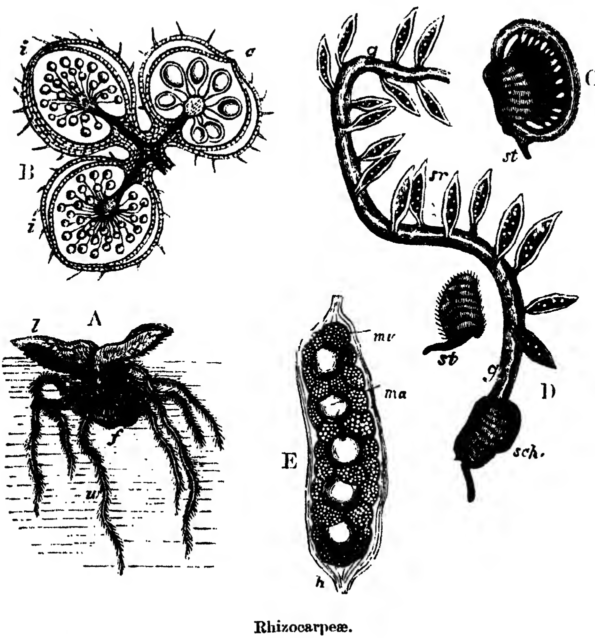
Affinities, &c.—From the point of view of its vegetative structure this Order is closely related to the Lycopodiaceæ, while it differs from it in the nature of its sexual reproduction, since in the Lycopodiaceæ the spores which produce the female and male prothallia are of the same size and form, and in the Selaginellaceæ macrospores produce female, and microspores male prothallia. The Order agrees, on the other hand, more closely with the following Order (Rhizocarpeæ) in the production of macrospores and microspores, but differs more widely from it in its vegetative structure.

Distribution, Qualities, &c.—*Selaginellæ* are delicate, and usually found climbing or creeping over low objects in damp and warm places. The *Isoëtes* grow in the mud at the bottom of pools. The corm is perennial and of a woody structure when old. They are more generally diffused in the northern hemisphere, whereas the *Selaginellæ* occur in greater abundance in warm climates. Neither have any recognized medicinal or economic properties. Many species of *Selaginella* are cultivated in greenhouses for the elegance of their foliage.

RHIZOCARPEÆ.

Diagnosis.—Asexual Generation: Small herbaceous plants floating on the water, or rooting in the mud at the margins of pools,

Fig. 496.



Rhizocarpeæ.

Salvinia natans. A, section through the plant, showing the whorls of aërial leaves *l*; at *w* the submerged leaves are shown bearing *f*, the sporocarps, nat. size. B, longitudinal section through three fertile teeth of a submerged leaf, showing at *a* a sporocarp with macrosporangia, and at *i i* two sporocarps with microsporangia: magnified.
Marsilea salvatrix. C, sporocarp which has burst in water and is protruding its gelatinous ring (Hanstein). D, the gelatinous ring: *g*, ruptured and extended; *sr*, compartments of the sporocarp; *sch*, covering of the sporocarp. E, compartment from a ripe sporocarp: *mi*, microsporangia; *ma*, macrosporangia.

with regularly branching stems bearing two or more series of leaves circinate in vernation. Stem grows by an apical cell giving off 2 or 3 series of segments, and the root by one giving off 3 series. The sporocarps are metamorphosed leaves containing in one or more chambers the sporangia, which spring from a central placenta, and bear one or more macrospores or numerous (4×16) microspores.—*Sexual Generation*: The macrospores produce the female prothallia,

and the microspores rudimentary male prothallia.—Illustrative Genera: *Salvinia*, Micheli; *Marsilea*, H.

Structure and Life-history.—The sexual generation of the Rhizocarpeæ strongly resembles that of the Selaginellaceæ. Here also the microspores produce the male prothallia. In *Salvinia* this is effected by the protrusion from the microspore of tubes, each of which divide into two cells at the apex, the contents of which form each four spermatozoids. In *Marsilea* and *Pilularia* the spermatozoids are formed within the microspore, thus: first eight cells are formed, and then the contents of each produce four spermatozoids—32 in all. The spermatozoids escape through a small funnel-like opening at one end of the microspore. The female prothallia are produced by the macrospores: they remain enclosed at first by the funnel at the apex of the macrospores and are bounded on the underside by a diaphragm, which separates it from a large intercellular space within. The funnel at the apex then opens asunder, and the prothallium is almost entirely protruded by a bulging motion of the diaphragm; on it are formed the archegonia, which after fertilization by the spermatozoids, give rise to the asexual spore-bearing generation.

Affinities, &c.—This Order is closely related to the preceding one (Selaginellaceæ) in the nature of its reproduction, and to the Filices in its vegetative structure.—The Rhizocarpeæ are aquatic or marsh plants. The genus *Salvinia* is represented by rootless plants which are found floating free in the water of stagnant pools; the submerged leaves are finely laciniated and resemble roots, but their segments bear sporocarps (fig. 496A, *f*). The genus *Marsilea* with its allies, of which *Pilularia* is our only native example, is composed of herbaceous plants, the stem of which is little developed and consists of a kind of rhizome giving off tufts of filiform adventitious roots on the underside and two or more series of leaves on the upper. They are found growing in the mud at the margins of pools.

Qualities and Uses.—They have no known medicinal or economic properties, unless perhaps *Marsilea salvatrix* (the Nardoo of Australia), the spores of which are said to have been eaten in cases of scarcity.

Division II. **Muscineæ.**

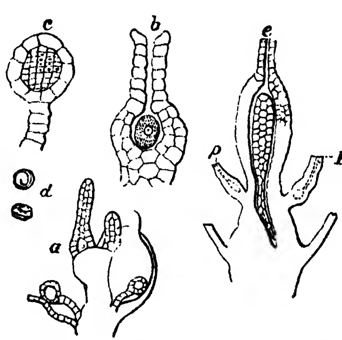
Cormophytal Cryptogams possessing imperfect vascular tissue only.

The *Muscineæ* consist of the Mosses and Hepaticæ, and resemble the Vascular Cryptogams in the fact that their life-history consists of two alternating generations—a sexual and an asexual. When the spore borne by the asexual generation germinates it produces the sexual generation. This is effected, indirectly in the case of the Mosses and a few Hepaticæ, by the production of a *protonema* (a confervoid prothallium), out of which the sexual generation arises, and directly in the other Hepaticæ. The sexual generation preponderates in the vegetative quality, and forms the plant commonly known as a Moss or a Hepatic, as the asexual generation does in the Vascular Cryptogams. It bears the *antheridia* (male organs) and the *archegonia* (female organs). From the fertilized central embryonic cell of the archegonium there arises the asexual generation

(sporogonium), which, in the course of its development, forms in an asexual manner the spores, which in turn produce the sexual generation.

When we compare the life-history of the *Muscineæ* with that of Vascular Cryptogams we find both a strong resemblance and a contrast. The resemblance consists in this, that both follow the scheme of alternating generations, one of which is endowed with sexuality and the other purely asexual, so far as a process of impregnation is concerned. How far the so-called asexual generation of Cormophytal Cryptogams may be sexually influenced by the other is a question on which we cannot enter here. The contrast consists in the fact that whereas in the Mosses it is the sexual generation which preponderates in the vegetative quality while the asexual generation is the more transient one, in the Vascular Cryptogams it is the opposite which is true. There are, however, two cases, one on each side (*Anthoceros* representing the Muscineæ and *Gymnogramme leptophylla*, Desv., representing the Vascular Cryptogams), in which this rule is abandoned and the relations approach each other. In the *Gymnogramme* it is the sexual generation (prothallium) which forms the more persistently vegetating plant, while the growth of the asexual (spore-bearing) generation scarcely exceeds that of the sporogonium of a moss. In *Anthoceros* the sporogonium (asexual generation) shows a greater vegetative tendency than is usually the case in the *Muscineæ*, by continuing to grow in the basal part and produce here new spores after those on the apical part are already ripe. These are exceptional cases; but since they occur in a perfectly normal manner they must be taken as constituting a form of alternation of generations intermediate between and connecting those occurring in Vascular Cryptogams and Muscineæ.

Fig. 497.



Antheridia and archegonia &c. of Hepaticæ: *a*, vertical section of the inflorescence of *Radula complanata*, with young (axillary) antheridia and (terminal) archegonia, magn. 50 diam.; *b*, vertical section of an archegonium, with germ-corpuscle, of *Jungermannia divaricata*, magn. 250 diam.; *c*, immature antheridium of *Radula complanata* (vert. section), magn. 250 diam.; *d*, spermatozoid; *e*, immature fruit, with surrounding epigone and two abortive archegonia (*p p*), of *Radula complanata* (vert. section), magn. 100 diam.

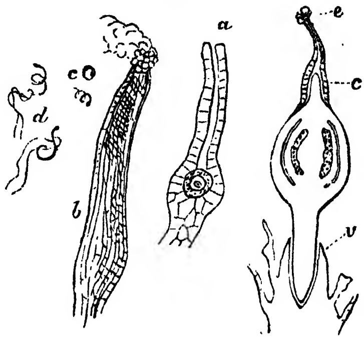
Both Liverworts and Mosses produce *antheridia* and *archegonia*, either on the same plant or on distinct individuals. There are minor differences of structure in the different groups of this Orders, some of which may be briefly described.

The *antheridia* of the Hepaticæ (and with these agree the same organs of Sphagnaceæ) are elliptical or globular sacs (fig. 497, *c*) formed of a single layer of cells; they are found imbedded in the thalloid stem of *Riccia*, *Pellia*, &c., or in the substance of the (male) receptacles of *Marchantia* (p. 434), or on stalks arising from the frondose stem in *Fossombronia*, and in the axils of the leaves in the foliaceous kinds of *Jungermannieæ* (fig. 497, *a*). The interior of the sac is filled with minute roundish cells, at first coherent, but ultimately free. These (the *sperm-*

cells) escape by the rupture of the sac of the *antheridium*, and each of them emits a 2-ciliated spiral spermatozoid (fig. 497, *d*).

In the Mosses the *antheridia* are larger and more elongated and cylindrical sacs, not stalked (fig. 498, *b*); they are found in the axils of leaves, sometimes scattered, but more frequently collected in axillary or terminal bud-like structures (*inflorescence*), either with the archegonia, or in a monœcious or diœcious condition. The antheridial sacs are filled with a tissue which is ultimately resolved into *sperm-cells*, which are discharged by the bursting of the sac (fig. 498, *b*); and when these escape (fig. 498, *c*) they in their turn emit an active, spirally twisted, 2-ciliated *spermatozoid* (*d*).

Fig. 498.



Antheridium, archegonium, &c. of Mosses: *a*, vertical section of archegonium with germ-cell from *Phascum cuspidatum*, magn. 100 diam.; *b*, antheridium of *Polytrichum commune*, bursting to discharge spermatozoids, magn. 25 diam.; *c*, sperm-cell and spermatozoid of the same, magn. 200 diam.; *d*, spermatozoids of the same, magn. 400 diam.; *e*, immature fruit of *Phascum bryoides* (vertical section), *c*, calyptra, *v*, vaginule, magn. 40 diam.

The *antheridia* and *spermatozoids* of Mosses may be readily observed in *Polytrichum commune*, the male plants of which form their "flowers" (*stellulæ masculinæ*) abundantly on every heath in spring.

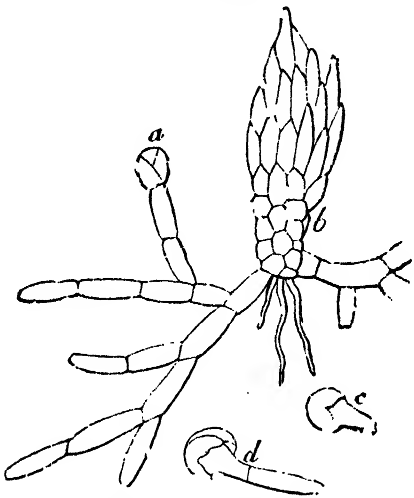
The *archegonia* are very much alike in Hepaticæ and Musci, being flask-shaped cellular cases, with a long neck (fig. 497, *a*, *b*; fig. 498, *a*), found generally several together, commonly at the ends of shoots, surrounded by modified leaves, which receive special names (pp. 431, 433), forming a kind of perianth. In *Anthoceros* the archegonium is formed in the substance of the thalloid stem. When mature the archegonia exhibit in their basal cavity a *germ-corpuscle* (fig. 497, *b*; fig. 498, *a*), which is fertilized by the passage of spermatozoids down the canal of the neck of the flask-shaped body. In any case this corpuscle is converted into a cell in one of the archegonia of a flower, the rest remaining barren (fig. 497, *p p*).

When the germinal cell is fertilized, it begins to grow by cell-division, and forms a cellular body which causes the expansion of the original wall of the *archegonium* (fig. 497, *e*). After a time, this wall gives way, in the Mosses by a circumscissile dehiscence, so that the upper part is carried upwards (fig. 498, *e*, *c*), afterwards becoming the *calyptra* of the sporogonium (fig. 500), while the lower part (fig. 498, *v*) remains as the *vaginule* (fig. 500, *c*). In the Hepaticæ the sac of the archegonium is usually ruptured in the upper part, and there is no cup-shaped calyptra formed, the sac becoming ultimately the envelope, corresponding to the vaginule of Mosses, here often called the *epigone* (p. 433, fig. 501 B, *a*).

The central cellular body (fig. 497, *e*) undergoes very remarkable changes: by degrees it exhibits different strata and regions, and in the

most perfect forms of this Class ultimately rises out on a stalk-like process from the vaginule (fig. 500, *v*), and becomes a *sporogonium* filled with spores (pp. 431, 433).

Fig. 499.



Germination of the spores of a Moss (*Funaria hygrometrica*): *c*, spore sprouting; *d*, more advanced, and the first cell divided; *a* and *b*, nascent leaf-buds on the confervoid protonema. Magn. 200 diam.

The mode of development of the spores, which are simple cells with a double coat, or a proper cell-membrane covered by a distinct *cuticular* layer, is briefly as follows:—In the cellular rudiment of the capsule concentric layers of the parenchyma become differently metamorphosed: the outer layers from the walls of the capsule and the sporangial membrane below, continuous with the *peristome* (p. 431) above; the central mass (in Mosses) is developed into the columella; the intermediate layers, which produce the spores, after multiplying to a certain extent, form free cells from the whole contents of each cell; the walls of the original or parent cells dissolve, and a cavity is formed. in which the free cells (parent cells of the spores) lie loose. These cells become divided into four chambers by septa; and each of these chambers (special parent cells of the spores) produces a single free cell from its whole contents. The last-formed cells, set free by the solution of their mother cells, are the spore-cells, which when ripe are found coated with a cuticular layer often more or less marked with points or reticulations, like pollen-grains.

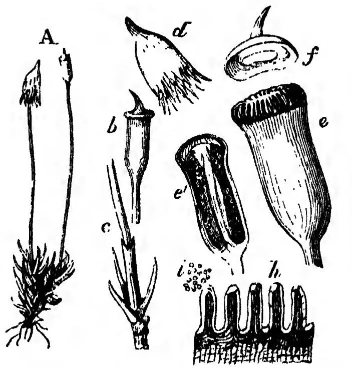
In the subsequent history, another kind of propagation takes place When the spores germinate, they produce a confervoid structure (*pro tonema*, fig. 499), from different cells of which are produced a number o

buds (*a*, *b*), each of which grows up into a new leafy stem, forming a tufted group of plants, which after a time fructify again by *antheridia* and *archegonia*.

MUSCI. Mosses.

Diagnosis.—Sexual Generation: Plants of a diffused or creeping habit, terrestrial or aquatic, with imbricated leaves arranged in from two to four rows, and branching in a monopodial manner. The stems are slender and contain no true vascular tissue. A true root is absent, but its functions are performed by root-hairs. The sexual generation arises as a lateral shoot from a protonema produced by the asexual spore on germination. It bears the antheridia and archegonia — the former stalked and the latter sessile on a narrow base. *The Asexual Generation* or *sporogonium* arises from the embryonic cell of the archegonium after fertilization by an antherozoid. Its first stage of development is passed in the calyptra, which, on being ruptured at the vaginula, is carried up on the apex, where the capsule which produces the spores is formed (figs. 497, 498, 500). Within the capsule is a sterile mass of tissue called the columella. The epidermis of the capsule splits to permit the escape of the spores.—Illustrative Suborders: *Bryaceæ*, *Sp*

Fig. 500.



Organization of Mosses:—A, *Polytrichum aloides*, natural size; *b*, its capsule, with operculum *in situ*, and calyptra (*d*) detached; *c*, the base of the seta, with the vaginule; *e*, capsule, with peristome, and, *e'*, a section of the same, showing the columella; *f*, the operculum of *e*; *h*, teeth of the peristome, from the mouth of *e*; *i*, spores, on the same scale of amplification as *h*.

In the Bryaceæ the leaves are small and scale-like and usually spirally arranged. The plants are of a cæspitose or diffused creeping habit. The antheridia and archegonia are produced either in terminal buds or in the axils of leaves. From the archegonium, the outer part of which is a flask-shaped sac, arises the sporogonium, which in its growth tears away the wall of the archegonium, leaving the base as a kind of collar (*vaginula*, fig. 500, *c*), and carrying away the upper part, which becomes more developed as a cap or hood (*calyptra*, *d*); this more or less encloses the urn-shaped *capsule* (*b*) until it is mature (fig. 500, A); the stalk of the sporogonium is called the *seta*. When the calyptra falls off it exposes the capsule, which in most cases has a deciduous lid (*operculum*, *f*); when

the lid falls off, the border of the mouth of the capsule is found either naked or furnished with a single or double fringe of teeth (*peristome, e, h*); and a circular piece, called the *annulus*, sometimes separates from the end of the columella in this place. The number of teeth in the peristome is either four or some multiple of that number. In the capsule of Mosses is to be found a columella or stalk-like mass of tissue running up the centre (*e'*). In the *Phasceæ* an operculum is absent, and the spores escape on the decay of the capsule. It differs slightly in its general structure from other *Bryaceæ*.—Illustrative Genera: *Phascum*, L.; *Grimmia*, Ehr.; *Tetraphis*, Hedw.; *Splachnum*, L.; *Dicranum*, Hedw.; *Trichostomum*, Hedw.; *Encalypta*, Hedw.; *Bryum*, L.; *Bartramia*, Hedw.; *Funaria*, Hedw.; *Polytrichum*, L.; *Hypnum*, L.; *Fontinalis*, L.

Sphagnaceæ consist of the species of one genus, *Sphagnum*. The plants are aquatic, and are commonly known as "Bog-mosses." They are of a peculiar yellowish-green aspect, with imbricate (5-rowed) leaves and fasciculate branches, the lower of which are long and deflexed. This genus differs very much from the *Bryaceæ* in habit and in the structure of its leaves. The chlorophyll-containing cells of the leaves are slender and elongated; in the interstices are large empty cells, the walls of which are strengthened by a spiral fibre. This structure causes the whitish or yellowish-green colour peculiar to them and to a few similarly organized Mosses. The antheridia are globose stalked bodies and resemble those of *Hepaticæ* more than those of Mosses. The sporogonium possesses a short turbinate seta, and a capsule which dehisces by an operculum, and is destitute of a peristome; the columella is short and does not reach the apex. A peculiarity of the asexual generation is the existence of sporogonia bearing spores of a smaller size than the ordinary large spores. This Order is remarkable for the share it takes in covering bogs and gradually furnishing material for peat, the lower parts of the stems gradually dying away below while the summit ascends; the descending lower branches of the fascicles bind the whole into a compact mass. They abound in cold and temperate climates in boggy places, furnishing an article of food to animals, and even to man in northern regions.

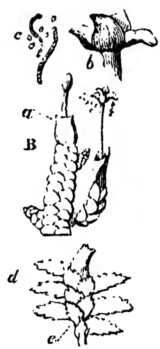
Andræaceæ are cæspitose Mosses with erect stems and imbricate leaves, and are natives of mountains and polar latitudes. The sporogonium has constantly a terminal position on the stems of the sexual plants and is destitute of a seta. The capsule is sessile on the receptacle where the *vaginula* arises and bursts vertically into four valves, which remain connected at the apex. A columella is present. In *Acrochisma*, a genus from the Antarctic regions, the valves separate only halfway down, as in the *Phasceæ* (*Bryaceæ*), in which *Archidium*, like *Andræa*, does not elevate the capsule on a seta, but carries up the calyptra simply by the expansion of the capsule. In the 4-valved dehiscence it agrees with the *Jungermanniaceæ* (*Hepaticæ*).—Illustrative Genera: *Andræa*, Ehr., and *Acrochisma*, Hook. fil.

HEPATICÆ.

The Scale-mosses are minute creeping plants with small, green, cellular (scale-like) leaves, imbricately arranged along the axis in two rows, often with a row of imperfect leaves (*amphigastria*, fig. 501, *d*) on the underside; or with the stem thalloid, *i. e.* forming a lobed leaf-like mass. The sporangia have oval capsules breaking through the summit of the calyptra, raised on a thread-like seta, and splitting vertically when ripe into 4 valves, which separate more or less widely into the form of a cross (fig. 501, B), scattering spores mixed with elaters, destitute of a columella.

The Jungermannieæ (or foliaceous Hepaticæ) have slender ramified creeping stems like those of branched Mosses, being more delicate, with leaves imbricated in a distichous manner, so as to give a flattened character to the branches (fig. 501, B, *d*). The *antheridia* and *archegonia* are produced on these stems; and from the latter are developed the *sporogonia*, which are surrounded at the base by modified *perichætial* and *perigonial* leaves and by a *vaginule* (fig. 501, B, *a*), which differs from that of the Mosses in being the entire sac of the archegonium, no hooded calyptra being carried up in the Jungermannieæ. The *vaginule* is sometimes called *calyptra*, and sometimes *epigone*; the circle of leaves, often confluent, surrounding it form the *perigone*, *perianth*, or *involucel*; and these are surrounded by the *perichætial leaves*, *perichætium*, or *involucre*. The capsules are generally elevated on thread-like stalks (*setæ*), and when mature split nearly or quite to the base into four teeth (fig. 501, *b*), which spread out more or less, and set free the *spores* and *elaters* (*c*). There is no columella.

Fig. 501.



Organization of Jungermannieæ:—B. *Radula complanata* with an unopened and a burst capsule: *a*, the vaginule; *b*, the burst capsule, magnified; *c*, spores and elaters; *d*, fragment of the leafy stem of *Jungermannia umbrosa*, showing the distichous arrangement of the leaves, and the *amphigastria* (*e*).

The genera of this Order, formed out of the old genus *Jungermannia*, present a considerable variety of conditions, both as regards their vegetative structure, which is either frondose or foliaceous, and the minute details of the organization of the *calyptra* (*epigone*), with the *involucel* (*perianth* or *perigone*) and the *involucre* (*perichætium*) which surround it. We have here a higher condition of the vegetative organs, nearer that of Mosses. The Jungermannieæ are found in shady woods and moist situations throughout all regions of the globe, and are most abundant in damp tropical woods. They have no important qualities.

The Anthoceroteæ are distinguished from the frondose forms of Jungermannieæ by the absence of an involucel (*perigone*). The *antheridia*

and *archegonia* are produced in cavities excavated in the thalloid stem; and from the archegonium springs a thread-like or pod-like *capsule*, which splits down longitudinally into two valves when ripe, and displays a central *columella*, and has both *spores* and imperfect *elaters*.—Illustrative Genera: *Metzgeria*, Radd; *Blasia*, Mich.; *Frullania*, Nees; *Trichocolea*, Nees; *Geocalyx*, Nees; and *Jungermannia*, Dill.

The Marchantieæ, or Liverworts, are minute green plants, with a stem in the form of a lobed, leaf-like, cellular expansion, rooting by capillary filaments below, with an indistinct midrib; the sporogonia depending from the underside of a capitate or radiate receptacle supported on a stalk arising from the apex, on the under surface, of the lobes of the frond; the capsules bursting by teeth or by irregular fissures, containing elaters mixed with the spores, but no columella.

The Thalloid Hepaticæ have a broad, more or less succulent, lobed, leaf-like expansion in place of stem and leaf (fig. 502); this is to be regarded as a foliaceously developed stem analogous to that of *Lemna* among the Phanerogamia. The sporogonia borne by the thalloid forms are very varied: the *Pelliceæ*, or frondose Jungermannieæ, bear capsules like those just described, but arising from the midribs of the thalloid stem; the Anthoceroteæ, Riccieæ, and Marchantieæ are very different.

Fig. 502.

Organization of Marchantieæ:—A. *Marchantia polymorpha*, bearing a receptacle of fruit; *b*, vertical section of the receptacle, showing the sporanges on its under surface: *c*, sporange bursting, with its vaginule and perigone laid open; *d*, spores and elater, highly magnified.

The thalloid expansion of the Marchantieæ sends up stalk-like processes from its marginal sinuses (fig. 502, A), terminating in simple or divided cap-shaped bodies (*receptacles*), on the underside of which are found the *archegonia*; the *antheridia* are in distinct heads; the archegonia develop into the capsules of the sporogonia (*b*), which usually burst at the apex (*c*) into four teeth, sometimes into eight; in certain genera a lid separates by transverse dehiscence, and in others the capsule bursts irregularly; the capsule has *no columella*, and its *spores* are mixed with *elaters* (*d*).

The Marchantieæ produce cellular bulbils or gemmæ. These are especially remarkable in some of the thalloid forms, as in *Marchantia*, where they are developed in groups in special cup-like receptacles.

The Marchantieæ grow in damp shady situations in all climates.—Illustrative Genera: *Fegatella*, Radd; *Plagiochasma*, Lehm.; and *Marchantia*, March.

The Ricciaceæ are inconspicuous *Marchantia*-like Liverworts, growing in mud or floating on water, having a delicate cellular leaf-like "frond," with the sporogonia, without an involucel or involucre, immersed in or sessile on the frond, bursting irregularly, and containing no elaters. The antheridia and archegonia are also imbedded in the substance of the

thalloid stem. From Anthoceroteæ they differ in the absence of a columella and of rudimentary elaters. They are interesting as exhibiting the lowest type of organization in the Class to which they belong. They are generally diffused, comprising 8 genera, with about 28 species. Genera: *Riccia*, Mich.; *Duriæa*, B. and Mont.; *Sphærocarpus*, Mich.

Class II. THALLOPHYTA.

Definition.—Cryptogamous plants producing in vegetation a thallus, presenting no opposition of ascending and descending axis, nor contrast of stem and leaf; antherozoids never spiral; reproduced by spores which are produced in parent cells, either forming part of the vegetating thallus or growing upon the surface of definite regions of the thallus devoted to reproduction. Spores not producing a prothallium, but reproducing the plant immediately.

These plants correspond to the Thallogens of most authors; their principal points of distinction from Cormophytal Cryptogams are above given. The vegetative structures of the plants of this group, which form their principal bond of connexion one with another, and their most striking character of distinction from the higher plants, present a great variety of conditions within their own limits. The *thallus* is a purely cellular expansion, presenting no contrast of parts analogous to that between the axis (stem) and the appendages (leaves and their modifications), which exists in the higher plants; hence they are necessarily devoid of true buds. A special regularity, however, and a determinate direction of growth are manifested more or less clearly in all cases, giving definite and characteristic forms to the *thallus*. This is the case even when the thallus is reduced to the condition of microscopic filaments, which elongate and spread in determinate directions. The *thallus* is exclusively composed of cellular tissue; and its more minute differences in the various classes and families of this division of the Vegetable Kingdom require microscopic investigation; but certain broad distinctions may be laid down, sufficient for the general discrimination of the classes in the more perfect forms. The lower forms of the two classes of Thallophyta approach very closely in their characters, on account of their great simplicity of organization, which excludes the possibility of many differential characters.

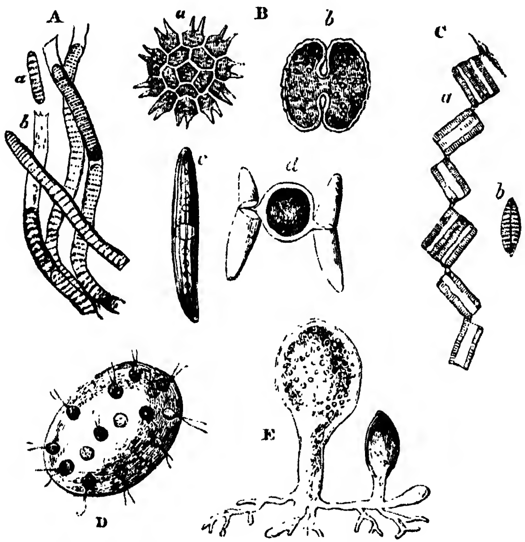
Division I. Algæ.

Gymnosporous Cryptogams living in water or in damp places exposed to the light, extremely variable in size, form, colour, and texture, free or attached by root-like organs, sometimes unicellular, at other times having a branched pseudo-stem and leaf-like appendages, sometimes of large size, but exclusively cellular in structure and destitute of stomata. Plants multiplied by subdivi-

sion of cells or by the formation of "zoospores." Reproduction or formation of spores effected by the antherozoids emitted from the antheridia, either on the same plant (monœcious) or on different ones (diœcious). Spores motionless, solitary, or in groups of four in a single sporange.

General Remarks.—The most familiar examples of this Class are the Seaweeds; but it also includes a great number of plants found in fresh water and in damp situations, many of which are altogether of microscopic dimensions, and invisible, except in quantity, to the naked eye.

Fig. 503.



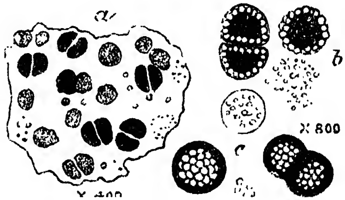
Algæ.—A. *Oscillatoria autumnalis*: *a*, filament escaped from the sheath, *b* (magn. 300 diameters). B. *Desmidieæ*: *a*, *Pediastrum Boryanum*; *b*, *Cosmarium margaritiferum* (200 diam.); *c*, *Closterium Lunula* (30 diam.); *d*, *Closterium acerosum* in conjugation, with the resulting spore (200 diam.). C. *Diatomaceæ*: *a*, *Diatoma vulgare*; *b*, end view of a cell (200 diam.). D. *Volvocineæ*: *Pandorina Morum* (100 diam.). E. *Botrydium granulatum* (15 diam.).

The lowest forms, the *Palmelleæ*, consist of simple cells, of most varied shapes, usually found connected together in definite or indefinite masses by gelatinous excretion or products of the decomposition of the older cells (figs. 504, 512, E, *a*). The individual cells, each often representing a distinct plant, are characterized by a wonderful diversity and, in certain families, beauty of form, as in the *Desmideæ* and *Diatomaceæ* (fig. 503, B, C); sometimes, as in the Volvocineæ, they are provided with vibratile cilia, and exhibit an active spontaneous motion (fig. 503, D). As a rule

their colour is green, an important exception to this being formed by the *Diatomaceæ*, which have another special peculiarity in the existence of a siliceous deposit in their walls, which remains as an indestructible skeleton after the decay of the organic matter of the plants. Some of these lower Algæ are found of red colour; but in many cases, at least, this colour is only characteristic of certain stages of growth of kinds which are green when vegetating actively. It is very probable that most of these so-called unicellular or pseudo-unicellular Algæ are really not independent organisms, but stages of growth of some other plant, perhaps of much higher structure. Thus there is reason to think that these unicellular bodies may not only be stages in the development of Lichens, but even of Mosses. One remarkable point in their history is the length of time they persist unchanged.

A step forward in complexity of organization is made in the filamentous Algæ, composed of cylindrical cells attached end to end, and thus forming long jointed tubes, either simple or more or less branched (fig. 512, C, p. 451): the Confervoideæ and their allies, the "silk-weeds" of fresh-

Fig. 504.



Palmella cruenta: *a*, mass of jelly with single cells, some dividing into two; *b*, detached cells and granules; *c*, cells treated with sulphuric acid and iodine, showing the cellular and granular contents.

water pools, afford familiar examples of this structure; these grow at the extremity of the filaments, or interstitially by all the joints elongating simultaneously.

The *Ulveæ* have a thallus where growth in breadth is added to that in length; some of them also acquire a certain thickness; in this way they become leaf-like expansions, of membranous texture. They grow by additions all round the margins of the anterior part, often lobed or divided, but of homogeneous tissue throughout: the form and dimensions of the thallus become more or less definite here; the colour is mostly green, as in the Confervoideæ.

The Red Seaweeds or Rhodospermeæ exhibit almost every possible form between that of the branched filamentous thallus and that of a highly compound or dissected leaf (fig. 510, p. 447) or a shrub-like collection of firm branches; and, moreover, the texture of the thallus varies from a simply membranous to a cartilaginous or even horny substance, caused by greater development of the cellular tissue, which in the higher kinds exhibits a distinction between the cortical or epidermal layer and the internal spongy parenchyma. The Corallines, which belong to this group, acquire a stony character from the deposition of carbonate of lime in their cellular tissue.

The colours vary in this Order; they are red, purple, brown, olive, &c., but never pure green, like the Confervoids.

The Olive-coloured Seaweeds, including the Fucaceæ (of which the "Bladder-wrack" is the commonest example), and others of very different organization, the Phæosporeæ and Dictyotaceæ, exhibit a similar gradation of form in the thallus. The lower forms of Phæosporeæ present tufts of branched filaments; the higher forms of these, and the Fucaceæ, have thick leaf-like or stem-like fronds of firm texture and sometimes enormous dimensions; many of them have a shrubby habit of growth, and attach themselves to stones &c. by discoid or branched expansions from the base, resembling superficially the roots of the higher plants, but having no similar function or anatomical character. The thallus of the larger forms is highly developed as to its tissues, having a distinct cortical layer; but the structure is strictly cellular, without a trace of woody fibre or vascular elements. The colour is here usually olive, brown, or some dull tint of green-brown; never bright green, as in the Confervoids.

Vegetative reproduction assumes a very important place in the multiplication of all Thallophyta. Throughout the Algæ it is a constant phenomenon, and one illustrating very beautifully the physiological homogeneity of the thallus. The lowest forms multiply by dividing into a number of cells or segments which grow up to the dimensions of the parent; this occurs as the ordinary mode of growth, here confounded with reproduction, in the *Palmelleæ* (figs. 504, 512, B, *a*, *b*), *Desmidieæ*, *Diatomaceæ* (fig. 503), &c. But another still more remarkable form of vegetative reproduction extends from these up to the highest Algæ, namely the reproduction by *zoospores*. This consists in the conversion of the semifluid contents of individual cells (the endochrome) into distinct corpuscles, and the expulsion of these from the thallus by the bursting of the parent cell-membrane (fig. 506, 509, 512, C, *d*); these corpuscles are filled with green or olive-coloured matter, except at one end, which is provided with cilia and is sometimes spoken of as the "rostrum." The cilia are excessively minute, and vary in number in different genera; sometimes the whole surface of the zoospore is covered by them. These zoospores are usually emitted at a fixed hour in the morning, as the result of an endosmotic action which causes the cell-wall to burst and set free the zoospores. Sometimes before their liberation they are seen to congregate in one portion of the cell, and, as it were, to strike against the cell-wall and cause its rupture. Their activity seems to be directly dependent on the influence of light. After moving spontaneously for some time, the zoospores lose their cilia, become encysted, and grow up into new thalli. In *Botrydium* and *Acetabularia* conjugation of the zoospores has been recently observed. In some Algæ, moreover, there are two sorts of zoospores—large ones, called *macrozoospores*, and smaller ones, called *microzoospores*. Pringsheim even describes a form of zoospore which has the faculty of remaining dormant for long periods, and even of resisting desiccation for several months, at the expiration of which time, if circumstances be favourable, it germinates and forms a new plant. To such zoospores the name of *chronizoospore* has been given. The formation of zoospores may take place in any or all of the cells of the thallus of the filamentous and foliaceous Confervoids; it occurs in certain definite parts of the thallus of the Phæosporeæ, where there is a difference in the constituent tissues. It has not been observed in the Red Seaweeds or the Dictyotaceæ—where, however, a distinct kind of organ is found,

called a *tetraspore* (fig. 510, *c*), which appears to be the representative of gemmiparous reproduction,—nor in Fucaceæ, where the only known kind of reproduction is by sexual organs.

Sexual reproduction has been made out clearly in Algæ belonging to the Confervoid and Fucaceous groups, and in the Rhodospermeæ. The Phæosporeæ at present are only known to produce *zoospores*. The essential phenomenon throughout is the emission from an *antheridium* of antherozoids which are endowed with a power of locomotion, and ultimately come into contact with a cell, which, in consequence, develops into a spore, which may be one of the ordinary cells of the thallus set apart for this purpose, or may be contained in a special fruit.

In the Confervoideæ, where the spores are developed from ordinary cells, there are no special reproductive organs; the spores formed in the impregnated cells acquire thick coats (fig. 512, *d*), usually assume a red or brown colour, and are set free by the decay of the parent cell.

In the Fucaceæ the fructification is limited to definite parts of the thallus. In *Fucus* or *Halidrys* (fig. 511), which may be taken as examples, the reproductive structures are formed at the ends of the lobes of the thallus. Externally the lobe (called the *receptacle*) presents a thickened appearance, marked with numerous distinct orifices (fig. 511); these orifices lead to chambers imbedded in the thickness of the thallus (called *conceptacles*, *b*), bearing on their walls cellular sacs of two kinds—one, the larger (*spore-sacs*, *e*), containing the spore-germs, the smaller (*antheridia*, *c*) containing *spermatozoids* (*d*) or impregnating corpuscles; both kinds of sacs burst and discharge their contents when ripe, and the spores are fertilized and encysted while swimming freely in the water.

The Rhodospermeæ and Dictyotaceæ, besides *tetraspores*, have *spore-sacs* and *antheridia*, mostly collected in "fruits" of definite form, sometimes in patches or lines (*sori*) on the surface of the thallus, like the sori of Ferns, sometimes imbedded in definite groups in its substance (called *favellæ*), sometimes projecting more or less from the surface or margins of the thallus (fig. 510, D, *d*, E), when they are naked or surrounded by a gelatinous or cup-like involucre (*favellidia*, *coccidia*, *ceramidia*). The *antheridia* are usually found arranged in groups in similar situations (fig. 510, F, *a*); and the *tetraspores* are either scattered or collected in fruits analogous to those containing the spores and antheridia (fig. 510, B, *c*). The antherozoids are immobile, and fertilize the sporange by means of a special tube projecting from the latter and called the *trichogyne*. Transformed branches containing imbedded tetraspores are called *stichidia*. The sexual organs are often found on distinct plants, which are thus diœcious.

The Oscillatoriaceæ are at present only known to increase by division—that is, vegetatively; the Phæosporeæ, again, are only known to propagate by liberation of zoospores from special cells of the thallus. The Dictyotaceæ and the Rhodospermeæ produce a peculiar kind of vegetative offset called a *tetraspore*, a body formed mostly in special localities or in groups, and consisting of a parent cell divided into four chambers, the contents of which, when set free from the parent plant, grow up at once into a new thallus. Besides the tetraspores, they have *spores* and *antheridia*. The antheridia produce minute, ultimately free vesicles, *spermatozoids* or *antherozoids*, according to Thuret devoid of cilia and

motionless; Derbès, however, asserts that he has observed them moving like undoubted spermatozoids. The *antheridia* are generally found in distinct plants from the *spores*, and the *tetraspores* in a third series of forms of the same species.

Where the sexuality of the Algæ has been ascertained, we meet with the process of fecundation under three different forms, and these forms in subordinate modifications. The three forms of the process are:—*Conjugation*, or complete union of a sperm-cell and a germ-cell, originally undistinguishable from each other by visible structure, occurring in Diatomaceæ and some Confervoideæ; *Fecundation of naked germ-corpuscles by ciliated spermatozoids*, which in the Confervoideæ occurs within the parent cell of the spore, and in Fucaceæ after both the germ-corpuscle and the spermatozoids have been cast off by the parent; and *Fecundation of naked germ-cells by motionless ovoid or globular spermatozoids through the medium of a special tube or trichogyne, as in* Rhodospermeæ. The importance of these phenomena to the whole theory of reproduction in plants renders it necessary to give a particular account of the processes as occurring in certain well-ascertained cases.

Conjugation.—In Diatomaceæ (including the *Diatomeæ* and *Desmidieæ*), the ordinary mode of multiplication of the plants is vegetative propagation, *by division*, resulting either in the formation of connected "families" of cells (fig. 503, C) or of an increased number of separate cells, or by the *extrusion of zoospores*, which are developed into new cells or cell-families (fig. 503, B, *a*). This kind of propagation goes on actively for a time under favourable circumstances; and the mere "division," at least, may be compared to the vegetative development of more complex plants.

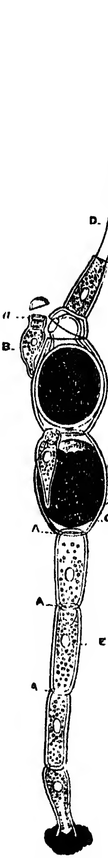
But at certain epochs this mode of increase is exchanged for another kind, in which we have cooperation of two originally distinct cells to produce the new one, indicating that it is a phenomenon of sexual reproduction, while at the same time there is no external evidence of difference in the concurrent cells. The genus *Closterium* (fig. 503, B, *c*) is multiplied vegetatively by division, or *fissiparous* propagation; at certain stages of existence, however, the cells which appear as if about to divide approach in pairs, and, a fracture of the external cell-membrane having taken place at the usual line of division, the contents of each cell, bounded by a primordial utricle, escape, come into contact with each other, and become confluent into a mass which assumes a rounded form (fig. 503, B, *d*). This round body becomes coated by a cellulose coat, and ultimately by a second, more internal. Its contents change from a green to a brown or yellowish colour: and the globular cell remains after the two empty parent cells have decayed. This globular body, which passes through a stage of rest before germinating, is sometimes called a *sporange*, not a simple spore, since its contents appear to become segmented and divide into a number of independent germs when the structure recommences active development.

An analogous conjugation of two cells takes place throughout the *Desmidieæ*, and it has also been observed in many *Diatomeæ*; in all cases the product is a resting sporangial cell or frustule, *i. e.* a cell possessing more than one firm coat, which produces two or more germs when about to throw off these coats to develop into a new plant of the form of the parent. Conjugation exhibits many minor variations in the groups of

Desmidieæ and *Diatomeæ*; and among unicellular Algæ it has been observed in the zoospores of *Botrydium*.

In *Spirogyra* (fig. 512, A, *a*), *Zygnema*, and one or two other genera of filamentous Confervoids, ordinary growth by cell-division is exchanged for a process of conjugation at certain epochs. Two filaments, lying side by side (fig. 512, A, *b*), exhibit papillary elevations of the cell-walls on the sides next their neighbours: these processes elongate until they come into contact; they then adhere, and the septum formed at the plane of union becomes absorbed, so that the two cells become connected by a tubular process, a kind of isthmus. The contents of the cells meanwhile retract themselves from the wall, lose their spiral appearance, and become condensed into a mass; then, in some cases, the whole contents of one cell travel through the isthmus into the opposite cell (*c*); in others, the contents of both pass into the isthmus, which expands into a globular cavity in the middle. In either case the contents of the two cells become combined, and they form a globular or oval spore, which produces two or three firm coats, enters a stage of rest, and remains after the parent filaments have decayed away (fig. 512, A, *d*). After a time, usually in the spring succeeding the formation of the spore, this germinates, bursting its coats and sprouting out into a new filament like the parent (fig. 512, A, *e*). This conjugation of *Spirogyra* and its allies has long been known, and was without a parallel for many years; but, as stated above, an analogous process occurs in *Diatomeæ* and *Desmidieæ* and other plants, and it is essentially related to the processes of fecundation by spermatozoids next to be described.

Fig. 505.



Œdogonium ciliatum: A, ordinary cells, in each of which a zoospore (E) is formed; C, C, sporangia; B, B, androspores, one bearing at *a* an antheridium, the lid of which is detached; D, extremity of the plant.

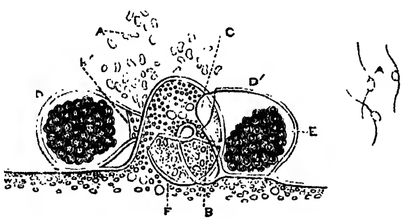
Fecundation by Spermatozoids.—The history of the fertilization in *Œdogonium* is one of the most curious points in the whole range of vegetable physiology, especially so as regards the male organs, which undergo a complex course of development as follows. On the same plant that produces the female spore, or in some species on another individual, are formed special cells called "microgonidia" or "androspores." The office of these cells is to produce ultimately antheridia, in which latter spermatozoids are formed. The androspores are formed in the ordinary cells of the plant, and escape from them by rupture of the walls of the parent cell as an ordinary zoospore would do, and like it they swim about in the water for

a time; but while an ordinary zoospore after a time germinates and forms a new thallus, the androspores attach themselves to the sides of the female spore or sporangium.

In this situation they grow into a sort of prothallus; the lower part becomes dilated or pear-shaped, while the upper extremity develops one or two small cells one over the other. These are the antheridia; and in each of them is formed a spermatozoid, the fecundating body. These latter, when mature, are ciliated and butt against the top of the antheridium, and at length cause its detachment in the shape of a little lid. In this manner they escape from the antheridium, move about for a time in the water by means of their cilia, and ultimately pass into the female spore through an opening previously specially prepared for its passage in the summit of the female spore. Here the spermatozoid comes into contact with a quantity of colourless granular mucilage formed in that situation prior to fecundation, the distention consequent on which seems to account for the formation of the aperture through which the fecundating body passes. The spermatozoid touches the mucilage, or even penetrates it to some extent, and becomes blended with it, and thus fertilizes the spore, which subsequently becomes invested by a cell-wall in the ordinary way.

Vaucheria is a genus of filamentous Confervoid Algæ, in which the long branched filament consists of a single enormously developed cell. This

Fig. 506.



Vaucheria: A, A, spermatozoids; B, C, horn-like antheridium; D, D′, sporanges; E, spore.

plant is commonly propagated by a peculiar kind of zoospore discharged from the thickened end of the filament or of its branches. But at certain epochs lateral structures are developed at the sides of the filaments, as branch cells, which become shut off from the main tube by septa; some of these processes expand into ovate and beaked or bird's-head-shaped bodies, others into short curled filaments or "horns." The former are *sporanges*, the latter *antheridia* (fig. 506). When ripe, the *antheridia* or "horns" discharge their cell-contents in the form of numerous spindle-shaped corpuscles, moving actively by the help of a pair of cilia. Meanwhile an orifice is formed in the beak of the sporange, and some of the spermatozoids make their way in, so as to come into direct contact with the cell-contents. This phenomenon is followed by the closing-up of the sporange by a membrane, and the conversion of its contents into a fertile *resting-spore*.

Sphæroplea is another genus of filamentous Confervoids, composed of two rows of cylindrical cells, in which fertilization of the resting-spores by spermatozoids has been directly observed (Cohn). In some of its cells

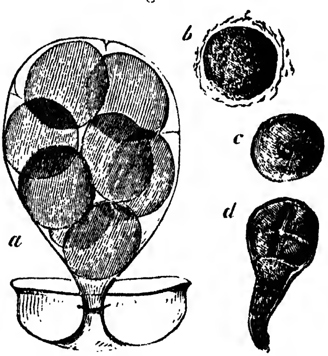
the contents are converted into a number of globular bodies, in others the contents are developed into numerous spermatozoids. When mature, orifices are formed in walls of the cells of both kinds; the spermatozoids escape from their parent cell, and make their way in through the orifices of the parent cells of the spores; the latter when fertilized produce their cellulose coat and ripen to resting-spores, which are set free by the decay of the parent filaments.

Analogous phenomena have been recently observed in various other filamentous Confervoids, as in *Œdogonium, Bulbochæte*; and Cohn has described a similar process in *Volvox*.

The mode of fertilization in the Florideæ, or Red Seaweeds, has been well made out by MM. Thuret and Bornet, who thus describe the process in *Helminthora*. A small cell, originating on the side of one of the dichotomous filaments of which the frond is composed, elongates, divides transversely, and becomes a short branchlet made up of four superposed cells, of which the uppermost alone continues to develop. Shortly there may be seen projecting from the summit of this uppermost division a little protuberance, which gradually lengthens into a long hyaline hair, often dilated at the extremity. This is the *trichogyne* or essential organ of fertilization. When the spermatozoids (here globular and motionless) come into contact with the upper part of this hair they adhere to it. Then the cell which forms the base of the trichogyne swells and divides into segments, and is soon transformed into a small cellular mass, which gradually forms the young "cystocarp" or mass of spores. The trichogyne gradually disappears. In *Callithamnion* the aggregations of spores called *favellæ* are formed from the side, not at the base, of the trichogyne, in consequence of fecundation by the antherozoid. Here, then, we have motionless antherozoids formed in the antheridium of one plant, escaping and coming into contact with the free end or style-like process of another plant; and, as a result of this contact, the cell at the base divides and subdivides into a mass of spores.

The observations made by Thuret on Fucaceæ are very decisive. In this Order the *conceptacles* produce in their interior bodies of two kinds, *antheridia* (fig. 511, *c*) and *spore-sacs* (fig. 511, *e*), either together or in separate conceptacles (monœcious), or in separate plants. The antheridia discharge 2-ciliated *spermatozoids* (fig. 511, *d*), which are poured out through the pores of the *receptacles* (fig. 511, *a*) into the surrounding water. At the same time the spore-sac (fig. 511, *e*) bursts and emits an inner sac (fig. 507, *a*), in which may be observed 2, 4, or 8 (*a*) spherical corpuscles, destitute of a cellulose membrane; this inner sac breaking loose, bursts and discharges its cor-

Fig. 507.



Development and fertilization of spores of *Fucus vesiculosus*: *a*, inner spore-sac bursting from the outer sac and about to liberate the spores; *b*, a free spore (devoid of cellulose coat) surrounded by spermatozoids; *c*, impregnated spore with a cellulose coat; *d*, the same germinating. Magn. 160 diameters.

puscles, which, like the spermatozoids, pass through the pores of the receptacle into the water. Here they become surrounded by a cloud of spermatozoids (fig. 507, *b*), which attach themselves to the surface, and by their ciliary movement cause the spheres to revolve. In the course of a few minutes, usually, a cellulose membrane is formed upon the surface of the globular corpuscle (by secretion from its primordial utricle?), and it becomes a cell (fig. 507, *c*), which subsequently germinates, growing by cell-division (fig. 507, *d*) into a new frond.

These observations upon the fertilization of the germinal corpuscles of the Algæ are of extreme interest, both as offering examples of the process of sexual conjunction, and as affording, like the development of zoospores, beautiful illustrations of the theory of free-cell formation by the production of a cellulose coat around a naked primordial utricle after it has been completely separated from the parent,—a phenomenon rarely met with in the higher plants, where this kind of cell-formation can only be observed in the interior of the parent structures, as in the embryo-sac of the Phanerogamia.

In the conjugating Algæ we observe the new cell to be produced by the complete union of the entire contents of the sperm-cell and germ-cell, which are undistinguishable from each other. In the other kinds cited, the contents of the germ-cell become converted into one or more globular corpuscles, rudimentary spores; while the contents of the sperm-cells are developed into numerous minute corpuscles, usually of a spindle shape (not spiral), moving actively by cilia. The corpuscles of the germ-cells acquire a cellulose coat and become cells; the spermatic corpuscles disappear after they come into contact with the nascent spores, either dissolving or becoming absorbed into the substance of the latter.

CHARACEÆ.

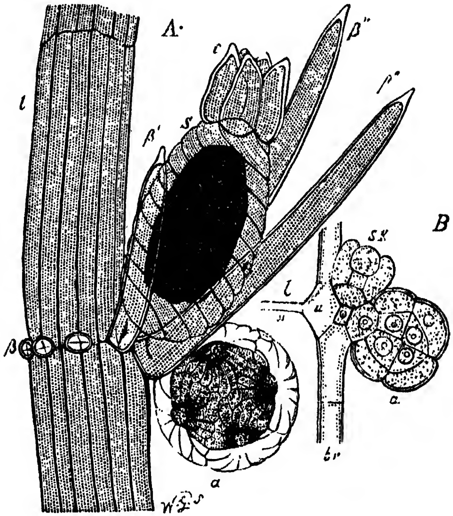
Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis.—Water plants having verticillately branched stems, rooting more or less at the joints; the stems either simple tubes, or with the central tube clothed by a cortical stratum of smaller tubes which grow over the internodes from the top and bottom and meet so as to envelope it. Reproductive organs of two kinds, found on the whorls of branches:—(1) axillary oval sporangia (*nucules*), consisting chiefly of a central cell with a cortex of spirally wound tubes ending in a crown of teeth above; and (2) little globular antheridia (*globules*), sessile on the branches, bursting when mature into 8 triangular valves, the centre of each valve bearing a stalk whence arise microscopic, jointed, confervoid filaments, each joint of which gives birth to a 2-ciliated filamentous spermatozoid. The nucules fall off, germinate, and produce new plants.—Illustrative Genera: *Nitella*, Ag.; *Tolypella*, A. Br.; *Lychnothamnus*, Rupr.; *Chara*, L.

Structure and Life-history.—The reproductive organs of this Family are very distinctly characterized, and borne in a conspicuous external

position. The two kinds, male and female, called respectively the *globule* and the *nucule*, occur either together on the same branch of the plant, on distinct branches, or on separate plants.

Fig. 508.

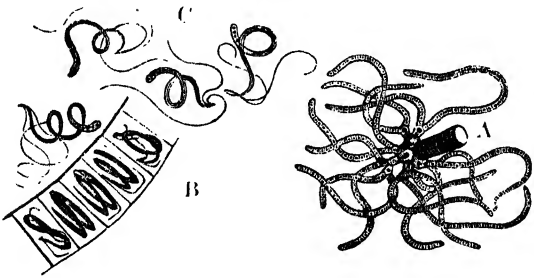


Chara fragilis.—A. Portion of branch: *a*, adult globule; *S*, nucule, *c*, its crown of teeth: β β'', sterile branchlets: × 50. B: *a*, globule in course of formation; *s k*, young nucule; *w*, nodal cell; *u*, basal cell between the base of the globule and of the nodal cell; *br*, cells of branchlet covered with cortex: × 350. (From Sachs.)

The *globule*, or *antheridium* (fig. 508), is a spherical case composed of eight triangular segmental pieces, each of which is formed of a number of cells radiating from a central one; all these have red or orange contents, imparting a colour to the *globule* as seen in its natural condition. From the central cell of each valve projects inward an oblong cell, the *manubrium* (fig. 509). These eight cells meet in the centre together with the apex of a flask-shaped cell which enters the globule at its base, forming the pedicle by which it is attached to the branch. Where these nine cells meet in the centre is found a little cellular mass, from which arise a number of slender jointed filaments. When the globule is mature, its valves separate, and each carries away its central cell, bearing a tuft of the jointed filaments. The cells forming the joints of these filaments are then seen each to contain a minute spirally coiled thread (fig. 509), which makes its way out and appears as a 2-ciliated actively moving *spermatozoid*, resembling those of the Mosses.

The *nucule* (fig. 508, *S*) consists essentially of a large oval cell surrounded by a double coat and, outside this, by five spirally coiled and intimately

connected cortical filaments. The five spiral cells terminate at the summit in five (or ten) teeth; and it appears that these teeth separate from each other at a certain epoch, leaving a free passage down the centre to the wall of the central cell. In this state we may compare the structure to



Nitella flexilis.—A, manubrium of segment of globule, with numerous filaments in which the antherozoids are developed; B, portion of filament, very highly magnified; C, antherozoids.

an *archegonium*, or to an *ovule* of Phanerogamia. The spermatozoids from the globule pass into the canal between the crown of teeth of the nucule, and cause it to become fertile. The product, however, of the fertilized central cell is not a free embryo or a spore, but it becomes itself the first cell of the new plant, like a spore. After fertilization the nucule drops off from the parent, passes through a stage of rest, and in the following season germinates like a seed or spore and grows up at once into a new plant. Pringsheim, however, states that the spore develops a true prothallus like that of the Mosses.

Distribution, &c.—The Characeæ grow in stagnant water, and many of them acquire a dull aspect and brittle texture by becoming encrusted with carbonate of lime, apparently precipitated from calcareous matter in the water, since it is often deficient in cultivated specimens. The unencrusted kinds, the simple tubes of *Nitella*, and the young shoots generally are well known as objects displaying in a beautiful manner the rotation of the cell-sap, which takes place throughout these plants. The abundant protoplasmic cell-contents cause these plants to give off a very offensive odour when decaying. The species occur all over the world, most commonly in temperate climates. They have no known uses, and are regarded as noxious from their smell when undergoing decomposition.

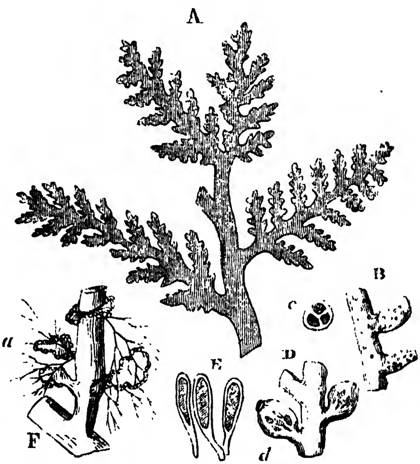
RHODOSPERMEÆ OR FLORIDEÆ. RED SEAWEEDS.

Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis—(Fig. 510.) Marine Algæ, mostly of a red-purple, rarely olive or brownish colour, with a thallus either foliaceous or of branched filaments, sometimes encrusted with carbonate of lime.

Reproduced by spores (E) formed in special sporangia, which are either superficial or plunged in the frond, and contained within special cavities or "conceptacles" (D) of varied form. The sporange is provided with a special tube, or "*trichogyne*," by means of which

Fig. 510.



Organization of Rhodospermeæ:—A. Part of a thallus or frond of *Laurencia pinnatifida*. B. A magnified fragment of a lobule with stichidia containing tetraspores like *c*, a more magnified figure. D. Lobule of the frond bearing ceramidia or spore-conceptacles; *d*, the spores. E. Spores from the same, more magnified. F. Lobule of a frond bearing antheridia, *a*.

it is fertilized by the antherozoid; accompanied by *antheridia* (F), containing a single motionless antherozoid without cilia, and by *tetraspores* (B, *c*), collections of 4 cells formed in special parent cells in similar situations to those of the spores.—Illustrative Suborders:—Subord. 1. RHODOMELEÆ: *Rhodomela*, Agh.; *Polysiphonia*, Grev. Subord. 2. LAURENCIEÆ: *Laurencia*, Lamx.; *Chylocladia*, Grev. Subord. 3. CORALLINEÆ: *Corallina*, Tournef.; *Melobesia*, Lamx. Subord. 4. DELESSERIEÆ: *Delesseria*, Lamx.; *Plocamium*, Grev. Subord. 5. SPHÆROCOCCEÆ: *Plocaria*, Nees; *Sphærococcus*, Grev. Subord. 6. CRYPTONEMIEÆ: *Phyllopora*, Grev.; *Chondrus*, Grev. Subord. 7. CERAMIEÆ: *Callithamnion*, Lyngb.; *Griffithsia*, Agh.; *Ceramium*, Adans. Subord. 8. POR- *Porphyra*, Agh.

Structure and Life-history.—In spite of the varieties of form presented in this Order, there is so close an essential agreement in their organization that they distinctly appear as members of one natural group, with characters whose value is only equivalent to that of some of the subdivisions of the

groups Fucoideæ and Confervoideæ of Harvey and others, with which they are usually placed parallel. The character of the spores seems to be the same throughout, although the fruits in which they are contained offer several successive degrees of complexity: the *favellæ* of *Ceramieæ*, and the *favellidia* of *Cryptonemieæ*, immersed or superficial groups of spores surrounded by a hyaline coat—the *coccidia* of *Delesserieæ*, hollow cases with thick membranous walls, containing a dense tuft of spores arising from a central peduncle—and the *ceramidia* of *Polysiphonia* &c., ovate or urn-shaped cases with thin and membranous walls, having a tuft of spores at the base—all these are but slight modifications of one (the conceptacular) kind of fruit, which produces the true spores. The various modes of arrangement of the *tetraspores* (which appear from Pringsheim's observations to be *gonidia*, or gemmulary bodies, since they grow up at once into a new thallus, while the other spores do not)—the scattered arrangement, the *sori* or definite groups, and the *stichidia* or metamorphosed branches enclosing tetraspores, have a like relation; and an analogous relation runs through the modes of arrangement of the *antheridia*, which, it may be mentioned, are rarely found in the same individuals of the species as the spores. The antheridia discharge minute spherical corpuscles, to which the best observers deny the power of spontaneous motion, as is the case in regard to the *spermatia* of Lichens and Fungi; but they are generally supposed to have a fertilizing function. The simpler forms of thallus occurring in this Order relate it to *Ulveæ* and *Confervoideæ*, while the existence of tetraspores, globular spores, and antheridia in the Dictyotaceæ makes that Order form a direct transition to the Fucaceæ. The mode of fertilization, by means of the antherozoids and the trichogyne, is described under the head of Reproduction, p. 439.

Distribution.—The Red Seaweeds are generally diffused, but diminish from warm temperate latitudes both to the equator and the poles. They occur in deeper water than the Olive Seaweeds, and below tide-marks, flourishing best in quiet bays.

Qualities and Uses.—The abundant gelatinous or horny substance of the thallus of many kinds, composed of a modification of cellulose related to gum and starch, renders them nutritious: *Chondrus crispus* is the "Carrageen" or Irish Moss; *Rhodymenia palmata*, *Iridæa edulis*, and other plants of the Order yield a similar excellent jelly when boiled. *Plocaria tenax* is largely used by the Chinese for making glue. Some have pungent qualities, as *Laurencia pinnatifida*, called "Pepper-dulse." *Plocaria Helminthochorton*, Corsican Moss, has the reputation of being anthelmintic. The *Corallineæ*, including common Corallines (*Corallina officinalis*) and "Nullipores" (*Melobesia*), long supposed to be of animal nature, are very curious on account of their complete interpenetration by carbonate of lime, giving them a brittle and sometimes stony character.

Dictyotaceæ are olive-coloured Seaweeds with a continuous thallus, bearing the reproductive organs in definite groups or lines (*sori*) upon the surface—the spores, tetraspores, and antheridia being all developed in an analogous manner from the cortical layer, bursting through its cuticular pellicle. This small Order is included by Decaisne in the Section Laminarieæ of the Tribe Aplosporeæ, but has been shown by Thuret to be quite distinct from the other Olive-coloured Seaweeds; it is

very interesting as presenting, in a special condition, exactly similar spores, tetraspores, and antheridia to those of the Rhodospermeæ, which they thus connect with the Fucaceæ, with which they agree in habit and with which they were formerly combined. They belong rather to warmer localities, and are more delicate than the Fucaceæ, sometimes, as in *Padina*, exhibiting attractive colours. They are of no known use.—Genera: *Dictyota*, Lamx.; *Dictyopteris*, Lamx.; *Taonia*, J. Agh.; *Padina*, Adans.

FUCACEÆ. Sea-Wracks.

Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis.—(Fig. 511.) Olive-coloured Seaweeds of gelatinous, cartilaginous, or horny texture, with a foliaceous or shrub-like or cord-like thallus, attaching itself to rocks by a simple or lobed and ramified discoid base; fructification in *receptacles* formed out of lobes of the fronds (*a*), the external surface of which is pierced with orifices leading to chambers (*conceptacles*, *b*) lined with filaments intermixed with *spore-sacs* (*e*) or filamentous *antheridia* (*c*), or both of these; the olive-coloured spores 4 or 8 in a spore-sac, from which they escape when mature, and are fertilized by the active 2-ciliated corpuscular spermatozoids (*d*) after they are detached from the parent. —Illustrative Genera: *Sargassum*, Rumph.; *Cystoseira*, Agh.; *Halidrys*, Lyngb.; *Himanthalia*, Lyngb.; *Pycnophycus*, Kütz.; *Fucus*, L.

Fig. 511.

Organization of Fucaceæ:—A. *Halidrys siliquosa*, half the nat. size: *a*, pods or receptacles; *b*, section through receptacle, showing the mouth of a conceptacle, the cavity of which is lined by antheridia (*c*) producing spermatozoids (*d*) and by spore-sacs (*e*).

Structure and Life-history.—Some of the filaments lining the conceptacles become, after a time, swollen and filled with brownish matter; this brown matter is developed into 2, 4, or 8 spores, which escape from a small orifice at the apex of the conceptacle, through which also subsequently pass the tufts of sterile hairs which do not undergo metamorphosis into spores. Sometimes the antheridia are present in the same conceptacles as the sporanges; or they are borne on a separate plant (diœcious). The antheridia consist of ovoid cells, some on branched threads and containing a whitish mass, interspersed throughout which are a number of red granules. The antheridia are ejected through the orifice of the concep-

tacle, and themselves give exit to numerous antherozoids, each provided with a couple of extremely fine cilia and containing a red granule. According to our present knowledge the Fucaceæ are strikingly separated from the other Olive Seaweeds—from the Dictyotaceæ by the absence of tetraspores and by the character of their antheridia, and from the Phæosporeæ by the absence of the reproductive zoospores and by other points of organization. They appear to be allied to the Confervoid forms, through Phæosporeæ, more closely than to Rhodospermeæ; but their reproductive organs are formed on a higher type.

Distribution.—Universal; especially found on rocks between tide-marks, or, if growing in deeper water, buoyed up to the surface by vesicular floats; very large in the Southern Ocean.

Qualities and Uses.—The gelatinous substance of which the thallus is composed renders some of these plants available as food for man or animals where better productions are scarce; but their chief value is as a source of iodine, extracted from the "kelp" or ashes, which were formerly an important source of soda also. The *Fuci* are also largely used for manure in maritime localities. *Sargassum bacciferum* forms the celebrated masses of "Gulf-weed" in the Atlantic Ocean. *Fucus vesiculosus*, the common Bladder-wrack, grows everywhere on our coast between tide-marks.

PHÆOSPOREÆ. OLIVE SEAWEEDS.

Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis.—Olive-coloured or brown Seaweeds with a foliaceous, shrubby, or branched filamentous thallus: reproduced by *zoospores*, having two cilia, one directed forwards, the other backwards, formed in clavate cells or multicellular filaments, collected in more or less definite groups on the cortical layer of the thallus of the larger kinds, in lateral tufts or terminal on the branched filamentous kinds.—Illustrative Genera: *Chorda*, Stackh.; *Laminaria*, Lamx.; *Dictyosiphon*, Grev.; *Punctaria*, Grev.; *Desmarestia*, Lamx.; *Myriotrichia*, Harv.; *Ectocarpus*, Lyngb.; *Myrionema*, Grev.; *Leathesia*, Gray.

Structure and Life-history.—This group corresponds to the tribe Laminarieæ of the group Aplosporeæ of Decaisne. The genera included in this Order with highly developed thallus approximate to the Fucaceæ, with which they are sometimes associated; but it has been discovered by Thuret that the so-called "spores" are sacs producing zoospores, which germinate and produce new plants like those of Confervoids: they are distinguished, however, from the zoospores of that group by the arrangement of the cilia, which are here two in number, unequal in size, and take reverse directions as they leave the body of the zoospore, resembling, in fact, the form exhibited in the spermatozoids of *Fucus*. The size and number of the zoospores are not constantly the same in the same plant; and in different cases the organs producing the zoospores are large clavate sacs or chambered filaments, the number of zoospores in a cell being either de-

finite or indefinitely great, on account of more advanced segmentation of the contents. The mode of reproduction and the forms of the thallus in such genera as *Ectocarpus* &c. bring this Order very near to the Confervoideæ. Much obscurity still prevails here, since antheridia coexist with reproduction by zoospores in *Cutleria*, and appear to exist in *Sphacelaria* and *Cladostephus*, which also reproduce by zoospores.

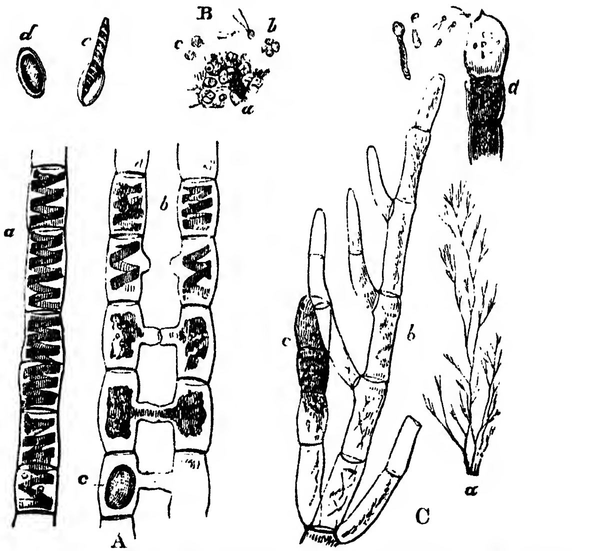
Distribution, Qualities, &c.—Much the same as in Fucaceæ. *Laminaria digitata* and *saccharina* are eaten (under the name of Tangle) on the coasts of the north of Europe, as also is *Alaria esculenta*.

CONFERVOIDEÆ. SILK-WEEDS.

Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis.—(Fig. 512.) Plants with a filamentous, membranous, gelatinous, or pulverulent thallus, growing in fresh or salt water, or on moist substances, of a bright green or, more rarely (often

Fig. 512.



Organization of Confervoid Algæ:—A. Filaments of *Spirogyra quinina*: *a*, in natural condition (magnified 50 diameters); *b*, two filaments conjugating; *c*, a spore formed in one cell from the mixed contents; *d*, a free spore; *e*, the same germinating. B. *Protococcus viridis* (magn. 200 diameters): *a*, a group of cells cohering by jelly-like matter; *b*, four cells formed by division of a cell of *a*, and two zoospores escaped from one of the cells, subsequently settling down as resting-cells, *c*. C. *Cladophora glomerata*: *a*, filaments, of natural size; *b*, the top of a branched filament, magnified; *c*, cells about to form zoospores; *d*, the same, with the zoospores escaping from the uppermost cell; *e*, zoospores germinating into new filaments.

temporarily), red colour, reproduced by zoospores discharged from the ordinary cells of the thallus (A, *d*), or by spores formed in these cells after impregnation by combination of the contents of two cells, either by conjugation (C, *c*), or by the transference of spermatozoids into the parent cell of the spore, the spores (C, *d*) passing through a stage of rest before germination.—Illustrative Genera: *Codium*, Stackh.; *Bryopsis*, Lamx.; *Vaucheria*, DC.; *Botrydium*, Wallr.; *Draparnaldia*, Bory; *Œdogonium*, Link; *Spirogyra*, Link; *Sphæroplea*, Agh.; *Coleochæte*, Bréb.; *Hydrodictyon*, Roth.; *Ulva*, Agh.; *Tetraspora*, Dec.; *Nostoc*, Vauch.; *Botrydina*, Bréb.; *Clathrocystis*, Henf.; *Palmella*, Agh.; (*Achlya*, Nees); (*Chytridium*, Al. Br.).

Structure and Life-history.—The specialities of the very multiform group represented by the above list of genera can scarcely be dealt with in a work like the present; and, in fact, our knowledge of the essential characters of the plants is at the present time undergoing a thorough revision. In the definition of the group of Confervoids here, the Oscillatoriaceæ and the other *permanently* active forms are excluded. The Oscillatoriaceæ are organized in a very different way from the true Confervoids. The Confervoids proper are mostly very simple cellular organisms, with chlorophyll and starch in the cells while they are actively vegetating; the majority discharge the cell-contents in the shape of one or many active zoospores, with 2 or more cilia at a beak-like extremity (*Vaucheria*, fig. 506, p. 442), or with cilia all over the surface; besides which process, sexual reproduction has been observed in *Zygnema* by *conjugation*, in *Œdogonium, Sphæroplea, Vaucheria, Bulbochæte*, &c. by spermatozoids derived from one cell entering the cavity of the parent cell of the spore; and in all probability this will be found general. The mode of fertilization will be found described at p. 441. The spores formed after fertilization become encysted in a firm coat, thrown off in germination, which commonly ensues only after a long interval. The *Palmelleæ* are forms not yet well explained, composed of solitary cells imbedded in a common mucus; they appear to stand at the lowest point of organization in the Vegetable Kingdom, if they be not stages of growth of higher forms (fig. 504, p. 437).

The genera above grouped by Professor Henfrey under the head of Confervoideæ are more naturally grouped by Decaisne under several distinct sections of varying degrees of importance as follows:—

1. *Confervæ*, comprising plants consisting of tubes or cells containing ovoid spores provided with 2–4 vibratile cilia.

2. *Unicellulares.* Plants consisting of a single cell producing numerous ciliated spores, which in *Botrydium* unite by conjugation (fig. 503, E).

3. *Œdogonieæ.* Filamentous Algæ, producing spores either by the aggregation of the green colouring-matter of the cell into a spheroidal mass, which escapes from the parent cell by a special aperture in its wall, and is then seen to be provided with a crown of vibratile cilia, or as the result of sexual agency. The antheridia consist of filaments, each cell of which contains 1 or 2 spermatozoids, which escape by the lifting of a lid-like valve of the cell-wall and fertilize the spore as above stated (see p. 441

4. *Vaucheriece.* Unicellular Algæ, producing two kinds of reproductive organs—the one resulting from the concentration of the green matter at the extremity of the filaments into an oval active spore covered with cilia, the other formed as a result of sexual agency. The antheridia appear in

Fig. 513.

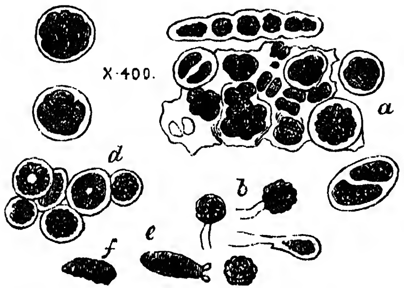


Fig. 514.

Fig. 513. *Protococcus viridis*, Henfr.: *a*, group of cells, the upper with eight in a linear series, those to the left dividing; *b*, zoospores set free by the solution of the cell-wall; *c*, cell dividing into two zoospores; *d*, resting-cells; *e*, zoospore with the cilia cast off; *f*, zoospore.
Fig. 514. *Palmella nivalis.*

the form of small horns placed in the proximity of ovoid sporangia. These antheridia contain numerous extremely minute spermatozoids, which escaping fertilize the sporangium and determine the formation of a spore, which does not germinate immediately, but only after the lapse of some time (p. 442, fig. 506).

5. *Synsporeæ* or *Conjugatæ.* Filamentous or unicellular Algæ, reproduced by the process of conjugation. This group comprises the Desmidieæ, of which further notice will be found hereafter.

6. *Diatomaceæ.* These are also alluded to in the following pages.

Distribution, Qualities, &c.—Met with universally in fresh and brackish water, some genera also on sea-coasts, growing on rocks, large Algæ, &c. Some of them occasionally appear suddenly in vast quantity, colouring lakes green; or, as in the case of *Palmella nivalis* (fig. 514), giving rise to the phenomenon called "Red Snow." *Palmella cruenta* (fig. 504) often

present

beautiful and varied forms under the microscope. *Ulva* (marine) produces large membranous fronds, which are sometimes eaten under the name of Green Laver.

Oscillatoriaceæ (fig. 503, A). Microscopic filamentous structures, usually collected into patches of definite or indefinite form, extending by peripheral growth, composed of continuous tubular sheaths enclosing a green or brown gelatinous matter marked by transverse striæ, where the substance is divided into longer or shorter pieces, often escaping from the

tube, ultimately resolved into discoid fragments, which, when free, become globular. The gelatinous "core," the vital part of the structure, is capable of a peculiar movement, which causes the free portions or extremities of the filaments to vibrate like a pendulum, or with a slightly vermiform *oscillation*, whence the name of the Order. Reproduction by spores unknown.

Our knowledge of the essential characters of this Order is imperfect; and the only mode of reproduction known is by simple division of the central substance of the filaments, the portions slitting out of the ends of the sheaths and secreting a new coat of their own. Their peculiar oscillating motion is one of the marvels of Vegetable Physiology; they appear to be totally destitute of cilia. Their movements, and the nature of their central substance (apparently devoid of starch, and coloured by different matters besides chlorophyll), seem to indicate a relation between Oscillatoriaceæ and Diatomaceæ, which would connect the latter with Confervoids. They occur in water, fresh and salt, and on damp earth everywhere.—Genera: *Oscillatoria*, Bosc; *Microcoleus*, Desmaz.; *Calothrix*, Agh.; *Rivularia*, Roth.

DIATOMACEÆ.

Class Algæ, *Endl.* *All.* Algales, *Lindl.*

Diagnosis.—(Fig. 503, B, C, page 436.) Microscopic unicellular plants, occurring isolated or in groups of definite form, usually surrounded by a gelatinous investment, the cells exhibiting more or less regular geometrical outlines, and enclosed by a membrane striated or granular, either simply tough and continuous, or impregnated with silex and separable into valves. Reproduction by spores formed after conjugation of the cells (*d*), by zoospores formed from the cell-contents, and by division.

ILLUSTRATIVE SUBORDERS.

Subord. 1. DESMIDIEÆ (fig. 503, B). *Cell-membrane without silica, containing chlorophyll and starch.* Closterium, *Nitzsch*; Cosmarium, *Menegh.*; Euastrum, *Ehr.*; Pediastrum, *Meyen*; Desmidium, *Agh.*

Subord. 2. DIATOMEÆ (fig. 503, C). *Cell-membrane impregnated with silex, valvular, containing a brown colouring-matter.* Eunotia, *Ehr.*; Diatoma, *DC.*; Navicula, *Bory*; Isthmia, *Agh.*; Melosira, *Agh.*

Affinities, &c.—These organisms were formerly included among Infusorial Animalcules; but the vegetable character is very strongly marked in *Desmidieæ*; and the reproduction by conjugation, characteristic of certain tribes of Confervoids, occurs not only in *Desmidieæ*, but in *Diatomeæ*, which in respect to general organization cannot well be separated from the *Desmidieæ*, although the nature of the cell-contents has more of the character of what we are accustomed to regard as animal substance The *Diatomeæ* are also remarkable for the way in which they divide by segmentation into a number of distinct frustules, each of which grows into a perfect plant.

Distribution.—*Desmidieæ* occur in all quiet pools of pure water, at the bottom or adhering to other plants. *Diatomeæ* are universally diffused, not only in fresh water, but in the sea and on moist ground, in all of which situations their siliceous cell-walls cause their remains to accumulate, if left undisturbed, until they form actual mineral strata.

VOLVOCINEÆ are microscopic bodies swimming in fresh water by the aid of cilia arranged in pairs upon the surface of a common semigelatinous envelope, the pairs of cilia each belonging to a green corpuscle resembling the zoospore of a Confervoid, imbedded in the periphery of the common envelope. Reproduction by the development of each corpuscle into a new colony, the whole being set free by the solution of the parent envelope, or by conversion of the corpuscles into encysted resting-spores like those of Confervoids. These curious and beautiful objects, found in similar situations with the Confervoids, appear more closely related to that group of organic beings than to any form distinctly recognizable as members of the Animal Kingdom, the persistence of the power of motion throughout the period of vegetative life being the only animal (?) character. —Genera: *Volvox*, Lam.; *Pandorina*, Ehrenb. (fig. 503, D); *Stephanosphæra*, Cohn; *Gonium*, Lam.

Division II. Fungi.

Cryptogamous plants consisting of long thread-like, tubular, generally branching hyphæ, or of branching series of cells interwoven into a mass which is in some cases microscopic in dimensions and in others of great extent, nourished on organic substances as parasites or as saprophytes, and entirely destitute of chlorophyll or similar pigments. Reproduction effected by both sexual and asexual means.

PHYCOMYCETES.

Diagnosis.—Fungi consisting of a mycelium of long, densely ramifying tubes, and bearing both sexual and asexual organs of reproduction. The asexual organs of reproduction (*zoosporangia*, *conidia*, and *sporangia*) are functionally of equal value with those produced by sexual agency (*oospores* and *zygospores*)—that is, the oospores or zygospores (as the case may be) produce either zoosporangia or conidia or sporangia, and on the same plant, but a little later, either oospores or zygospores again; the first or asexual class of these also reproduce both themselves and the second or sexual class a little later.

This Order may be divided into three Suborders, in which the habits of life and growth vary.

Suborder 1. SAPROLEGNIEÆ.—Fungi growing for the most part in water, and chiefly on the dead bodies of insects, and consisting

of a mycelium of long, densely interwoven hyphæ, which bears both sexual organs—*antheridia* (male organs) and *oogonia* (female organs) —and asexual *zoosporangia*. The contents of the oogonia, when fertilized by the antheridia, are called oospores, and on germinating produce a mycelium which bears first zoosporangia and later the sexual organs. The zoosporangia on bursting produce zoospores which, after a short motile state, come to rest, germinate, and form a mycelium which produces again zoosporangia, and later the sexual organs. The zoospore, therefore, which has an asexual origin is, functionally, of equal value with the sexually produced oospore.

Oospores

Zoosporangia — Oospores

Zoosporangia, Oospores. — Zoosporangia, Oospores.

ILLUSTRATIVE GENERA: *Pythium*, Nees; *Saprolegnia*, Nees; *Aphanomyces*, De Bary; *Achlya*, Nees.

Structure and Life-history.—In the forms which Pringsheim calls monœcious the antheridia and oogonia are produced beside each other on the same plant; but in the others, first antheridia and then oogonia. The oogonia are usually situated at the end of short branches of the mycelial hyphæ, and are very rarely interstitial. In the monœcious forms they are globular cells, rich in protoplasm, which is at first equally distributed. In *Saprolegnia monoica* the cell-membrane is resorbed at numerous places, and has a perforated appearance. At the same time the protoplasm gradually separates into several portions, which become rounded off and float together in a watery fluid within the oogonium, each bounded by a smooth superficies which does not consist of cellulose. In *Pythium*, *Aphanomyces*, and several species of *Saprolegnia* the whole of the protoplasm within the oogonium contracts into one of these globes, which, floating in the watery fluid, takes up its position in the middle of the oogonium. During the formation of the oogonium, the antheridia or antheridium, as the case may be, grow out from the same branch of the mycelium or from neighbouring hyphæ in the form of thin, cylindrical crooked twigs, often wound round the stalk of the oogonium. The upper ends adhere to the wall of the oogonium, swell slightly, and become bounded at the base by a septum. At the time of the formation of the globular bodies within the oogonium, each antheridium pushes through the wall one or more tubes, which open at the points and discharge their contents. These contents are minute motile corpuscles, scarcely $\frac{1}{500}$ millim. in size, and are the fertilizing spermatozoids. The globular bodies after being fertilized are provided with a cellulose membrane, and receive the name of oospores.

In the diœcious forms (e.g. *Saprolegnia dioica* and *Achlya dioica*) the oogonia and their globular contents are formed as in the monœcious species. The antheridia, on the other hand, are formed in thick bladder-like protuberances which arise at fixed times on the mycelium, and are divided

by transverse walls into a series of cylindrical cells, each of which represents an antheridium. In *Saprolegnia dioica* the whole of the protoplasm of the antheridium separates into numerous minute spermatozoids, which are discharged in a motile state from an opening in a narrow protuberance of the wall of the antheridium. In *Achlya dioica* the contents of the cylindrical antheridium are divided into a number of portions (of about the size of the zoospores of the species). These in their turn break up into small spermatozoids, which emerge first from their special mother cells and then from the antheridium, in the same way as in *Saprolegnia dioica*. The spermatozoids of both species move by means of a long cilium. It is to be assumed, from the analogy of closely related *Algæ*, that the spermatozoids enter through the holes in the walls of the oogonia and fertilize the globular bodies by union with them; but there is not enough direct evidence to warrant more than an assumption.

The ripe oospores of *Saprolegnia* (so far as they are yet known) possess a membrane consisting of two coats, and produce germ-tubes after a period of rest. They have also been known, but exceptionally, to produce zoospores after a short period of rest.

Suborder 2. PERONOSPOREÆ.—Fungi parasitic on living Phanerogams, and consisting of a mycelium of densely ramifying hyphæ, which bears both sexual organs—*antheridia* (male organs) and *oogonia* (female organs)—and asexual *conidia*. They resemble strongly the preceding family, *Saprolegnieæ*. The mycelium which ramifies within the host-plant first bears the conidia either singly on branching tree-like (*Peronospora*), or in a vertical series on club-shaped (*Cystopus*) *conidiophores*, which appear upon the surface of the affected part of the host-plant. According to the species the conidia are either simple spores, which reproduce the mycelium by emitting germ-tubes directly, or zoosporangia (as in certain species of *Peronospora*, *Phytophthora infestans*, and *Cystopus*), the germinating zoospores of which give rise to a new mycelium. This new mycelium in both cases produces conidia again, and later the sexual organs. The germinating oospores also produce a mycelium, which bears both conidia and, afterwards, the sexual organs. The asexually-produced conidia here (like the zoosporangia in the *Saprolegnieæ*) are functionally of equal value with the sexually-produced oospores.

Oospore

Conidia | Oospores

Conidia, Oospores. | Conidia, Oospores.

ILLUSTRATIVE GENERA: *Peronospora*, Cord.; *Phytophthora*, De Bary; *Cystopus*, Lev.

Structure and Life-history.—The reproduction of the *Peronosporæ* so strongly resembles that of the monœcious forms of the *Saprolegnieæ* that

a comparative description only will be necessary. The oogonia arise at the end of short branches of the mycelium in the intercellular spaces of living Phanerogams, and resemble those of the monœcious *Saprolegnieæ* both in form and in being rarely interstitially situated on the mycelium. The antheridium grows either on the same branch or a neighbouring one, and is also similar in form to those of the monœcious forms of the preceding Order. The process of fertilization is carried out as in it too, only that the protoplasm within the oogonium *constantly* contracts into *one* globular mass. Professor de Bary records that he never found developed oogonia without an antheridium, and extremely seldom such as had two. The oospores germinate after a long period of rest, usually lasting throughout the winter. Two forms of germination have been observed. In *Cystopus candidus* the oospores burst and produce the same number of zoospores as the asexual conidia (zoosporangia). In *Peronospora Valerianellæ* the oospores produce each a germ-tube which, by repeated ramification, forms a new mycelium. The conidia also, as already stated, either produce germ-tubes or zoospores according to the species. The mycelium of *Cystopus* is provided with numerous organs called *haustoria*, which, in the shape of small bladders, penetrate the cell-walls of the host-plant and extract the nourishment for the use of the fungus.

The well-known potato-disease is caused by a fungus belonging to this family. It was, until lately, known as *Peronospora infestans*; but, in a recent work on the subject, Prof. de Bary considered it to have separate generic characters, and it now bears the name of *Phytophthora infestans*.

Suborder 3. Mucorini (fig. 1 D, p. 8).—Fungi growing on organic solutions, and consisting of a densely branching mycelium, with no transverse septa up to the time of fructification, and bearing both sexual organs and asexual *sporangia*. The result of the union of the conjugating sexual bodies is called a *zygospore*. The asexual *sporangia* are here (like the similar organs in the two preceding orders) functionally of equal value with the sexually produced zygospores.

Zygospore

Sporangia | Zygospores

Sporangia, | Zygospores. | Sporangia, | Zygospores.

Illustrative Genera: *Mucor*, Mich.; *Syzygites*, Ehrb.; *Rhizopus*, Ehrb.; *Pilobolus*, Tod.

Structure and Life-history.—The sporangia are similar in function and in some degree in structure to the zoosporangia and conidia of the *Saprolegnieæ* and *Peronosporeæ*. They appear at the end of sporangia-bearers, which, up to the time of fructification, are, like the mycelium, without septa. The spores contained by the sporangia germinate by means of germ-tubes and form a mycelium by repeated ramification. This was for long the only form of reproduction known in the *Mucorini*, and it is only in recent times that the researches of Professor de Bary and others have

brought to light another and a sexual means of reproduction, which is described in the cases of *Rhizopus nigricans*, Ehrb., and *Syzygites megalocarpus*, Ehrb. These cases are, with the exception of unimportant details, similar, and it will be sufficient to describe the process as it occurs in the former. The conjugating cells of *Rhizopus nigricans* are elongated, stout, irregularly branching and interwoven tubes. Where two meet each pushes against the other a protuberance, at first cylindrical and of equal thickness with itself. They remain closely attached and soon grow to a considerable size, in thickness chiefly. At the end of each a separate cell is formed by the growth of a partition. These two cells are usually of unequal size—one as long as it is broad, and the other only half as long as its breadth. The original membrane which separated them now becomes perforated in the middle, and soon vanishes altogether; the two conjugating cells then unite and form a *zygospore*, which increases rapidly in size, and usually attains a diameter of over one fifth millim. It is, as a rule, drum-shaped; the ends smooth, and the free surface clothed with wart-like protuberances. The contents are of coarsely granular protoplasm, often accompanied by large drops of oil. The germination of the zygospore, as observed in *Syzygites*, is by means of a germ-tube, which by repeated dichotomous branching, at the expense of the stored-up matter in the zygospore, soon forms a new mycelium bearing asexual sporangia. Professor Strasburger has very recently proposed the name of *gametes* for the conjugating cells, and *zygote* for the *zygospore*. Professor de Bary has further suggested that when the *gametes* are *stationary*, as in this Order, they should be called *aplanogametes*, to distinguish them from *motile* conjugating bodies found in *Algæ*, which he would call *planogametes*. The substitution of zygote for zygospore is on the ground that the organ in question is not the equivalent of a *spore*, but of a fertilized *ovum*. This nomenclature, if accepted (and it is time that some such rational system were introduced), will necessitate the substitution of other words for the terms oospore, &c., in other Orders.

The *Mucorini* are usually to be found growing on horse-dung and decaying substances.

HYPODERMII.

Diagnosis.—Fungi parasitic on living plants, and consisting of a mycelium of interwoven hyphæ bearing asexual organs of reproduction (spores) either in definite or irregular receptacles.

This Order is divided into two Suborders as follows:—

Suborder 1. Uredineæ.—Fungi parasitic on living plants, and consisting of hyphæ woven into definite fructiferous receptacula, at first situated beneath the surface of the affected part, but at length bursting out. The reproductive organs are of an asexual character, no sexual organs being as yet known, and take three consecutive forms, arranged so as to form a cycle of generations on two different host-plants.

Teleutospores.
|
Æcidium-spores accompanied by spermogonia.
|
Uredospores, and later on the same mycelium teleutospores again.

ILLUSTRATIVE GENERA: *Puccinia*, Lk.; *Æcidium*, Lk.; *Uromyces*, Lev.

Structure and Life-history.—The life-cycle of these parasites begins with the germination of the teleutospores—thick-walled spores situated at the end of filiform *basidia*, either singly or in pairs, according to the genus to which they belong. The germination takes place in spring, and consists in the emission of a germ-tube, which rapidly forms a promycelium bearing three or four sporidia. These sporidia also soon push out germ-tubes, which, if on a suitable host-plant, penetrate the epidermis-cells and form a mycelium within the parenchyme. After a few days this mycelium begins to form a new fructification under the epidermis of the host-plant, which eventually breaks out under the forms of the Æcidia and their constant companions the spermogonia. The latter appear first. Round them, or irregularly among them, are the Æcidia. The spermogonia are in shape small narrow-necked sacs of the same colour as the Æcidia. They were formerly believed to be different species of Fungi from the Æcidia, but Tulasne has shown that they belong to the same. In them are found minute bodies, called spermatia, which Tulasne believed to be male organs (spermatozoids), since he found them incapable of germination; but no female organs have as yet been found. It was also suggested that they stood in a sexual relation to the Æcidia, near which they are constantly found; but Professor de Bary has cultivated true Æcidia, the spores of which germinated, on a plant on which was found no trace of spermogonia or spermatia. The subject is at present wrapt in mystery. The Æcidia consist of at first round or oval, and after bursting basin-shaped receptacula, the walls of which are composed of pseudo-parenchyme (short, polyhedral, closely fitting mycelium-cells). At the base of this body is the hymenium—a circular layer of short, cylindrical, club-shaped upright basidia, on each of which rests a series of spores in regular order, one above the other. The spores are of a round polyhedral form, and filled with protoplasm coloured red or yellow by oil. On the bursting of the enclosing peridium of pseudo-parenchyme the spores are liberated in a state capable of germination, which takes place in the form of short crooked germ-tubes that penetrate through the stomata of the next host-plant, and form rapidly a new mycelium in the intercellular spaces. Again, after a few days, this mycelium forms a new fructification—the Uredo. The Uredo is at first of the shape of a flat circular cushion lying immediately under the epidermis of the affected part. On it arise filiform basidia, each of which bears a round or oval spore—the Uredospores, which during their formation break through the epidermis. The Uredospores germinate rapidly and reproduce *themselves* constantly, and to this quality is the rapid and extensive spreading of this disease to be attributed. The same mycelium which begets the Uredo, afterwards forms the teleutospores from which we started. The teleutospores hibernate and germinate again in spring, as we have seen, and so every year the disease passes through the same cycle of generations.

The host-plants affected by the same species are usually of two very different kinds. The teleutospores and Uredospores affect chiefly the *Gramineæ*, and prove very destructive to that useful order of plants. The Æcidiumspores are not so much confined to one order of plants, but affect usually the *Compositæ*, *Ranunculaceæ*, *Leguminosæ*, and *Labiatæ*, to which they are by no means so destructive as the teleutospores and uredospores are to the *Gramineæ*.

Until recently the different generations of these Fungi were taken to represent different genera, and even now they are, we need not say erroneously, so described by many mycologists on the plea of convenience. The Æcidiumspores represent the genus "*Æcidium*," the Uredospores "*Uredo*," and the teleutospores "*Puccinia*," and "*Uromyces*." Each generation of each species has its peculiar host-plant, and of a not inconsiderable number there is only known one or two generations—the *Æcidium* only in some cases, and the *Uredo* and *Puccinia* only in others.

To M. Tulasne and Professor de Bary belong chiefly the honour of having worked out this remarkable life-history.

Suborder 2. Ustilagineæ.—Fungi parasitic on living plants, and consisting of interwoven hyphæ, which bear asexual spores irregularly. Spores sooty-coloured, either solitary, in series, or in masses, at first enclosed, but at length bursting out and escaping easily, from the slender nature of the threads which bear them. The whole life-cycle, so far as yet known, consists in the formation by the germinating spores of sporidia, which, on suitable host-plants, germinate and form a mycelium on which the spores are again directly formed.—Illustrative Genera: *Ustilago*, Fr.; *Tilletia*, Tul.

Structure and Life-history.—The habit of life of this order is similar to that of the preceding one. In it the life-history, so far as it goes, is also of the same nature. When the spores, which correspond to the *teleutospores* of *Uredineæ*, germinate, a promycelium is formed as in that Order, bearing sporidia, in some cases sessile and in others slightly stalked. It appears also that successive sporidia may be formed at the same place. These sporidia germinate in the usual manner and form a new mycelium in the tissues of a suitable host-plant, which mycelium directly produces again the spores from which we started. The *Ustilagineæ* are very injurious, especially to the *Gramineæ*. Kuhn and Hoffmann observed that the sporidia attack the axis of the germinating plants, in which they develop a mycelium, which is carried up with the growing plant, and ultimately produces spores in the fruits and causes their destruction. The power of producing successive sporidia tends largely to cause the plentiful distribution of the Order.

BASIDIOMYCETES.

Diagnosis.—Fungi growing on dead organic matter and stumps of trees, and consisting of hyphæ interwoven, so as to form a fleshy, gelatinous or woody thallus (vulgarly considered the plant), but

which is the receptacle of the hymenium. Hymenium bearing usually quaternately asexual spores at the apex of erect basidia. Spores reproducing the plant directly without the intervention of any intermediate generation. Mycelium comparatively small and floccose. The Order may be divided into the following Suborders:—

Suborder 1. TREMELLINI.—Fungi growing on stumps of trees and on the ground, of a gelatinous consistency, with sometimes a denser nucleus, immarginate or cup-shaped. Hymenium bearing two distinct kinds of basidia in different genera. Spores reniform, in some cases divided, and in others not.—Illustrative Genera: *Tremella*, Dill.; *Dacrymyces*, Nees.

Structure and Life-history.—In the genus *Tremella* the basidia are at first subglobose or quite spherical, and divided from top to bottom into four equal parts. These segments either remain united or become divergent from each other, while they grow out to the margin of the fungus in the form of long hyphæ, and produce there generally undivided and kidney-shaped spores. In *Dacrymyces* and *Guepinia* the basidia are at first claviform, but subsequently grow out in the form of two thick diverging arms, on each of which is produced one reniform spore.

There are usually present in these plants in great abundance very minute spherical or ovoid spermatia, produced in regular spermatophorous apparatus. Their function is unknown. The ordinary spores reproduce the plant directly. The consistence of these plants is very gelatinous and collapses on drying. If, however, they be placed in water, they very soon absorb it, and become again distended to their former extent; and this property is found to be of great use in examining old specimens.

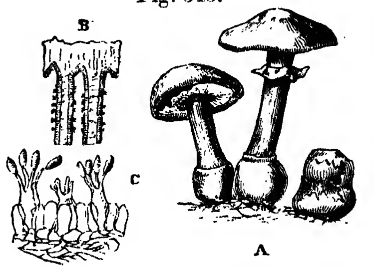
Suborder 2. HYMENOMYCETES.—Mycelium floccose, giving rise to a superficial hymenium on which are produced clavate *basidia* bearing at the apex usually quaternately, slightly stalked or sessile spores. The substance of the plants varies from gelatinous to woody.—Illustrative Genera: *Agaricus*, L.; *Boletus*, Fr.; *Polyporus*, Fr.; *Hydnum*, L.; *Corticium*, Fr.; *Clavaria*, L.

Structure and Life-history.—This group is the best known of all the Fungi, and includes the common Mushroom, to which all its members bear more or less resemblance in organization and reproduction. The common form is that of a pileus raised upon a stalk or stem, and bearing on the under surface lamellæ or gills (*Agaricini*), pores (*Polyporei*), or teeth (*Hydnacei*), on the surfaces of which are situated the basidia, which bear the spores (fig. 515). The spores are the only reproductive organs and, so far as is yet known, are asexual in their origin. On germinating, they give rise directly to a new mycelium, which bears again the spore-producing plant. Attempts have been made at different times to discover the existence of a sexual agency in the production of these spores, but as yet unsuccessfully. Among the basidia are seen other cells of similar shape and usually larger size, called cystidia; and it was at one time contended that they were male organs, but no special function seems to belong to them. They are probably only barren basidia. The mycelium is entirely, or

nearly so, underground, and that part which is commonly called the fungus is the receptacle.

The *Agaricini* are distinguished from the other Hymenomycetes by the hymenium being always inferior, and spread over the surface of gills which radiate from the stem. The gills may be either simple or branched, and attached to or distinct from the stem. The spores vary in colour; but one colour is constant as a rule to a genus, unless in the case of the large genus *Agaricus*, where the colour of the spores is used as the basis in forming groups of the different subgenera. The stem is sometimes cartilaginous, and sometimes fleshy, and also varies in colour, but according to the species and even to its age. There is to be found on the stem in some genera and subgenera a ring or *annulus*, which is all that remains of a veil or covering (*velum partiale*) which united that part of the stem with the outer edge of the cap or pileus, but was ruptured on the expansion of the latter. In certain subgenera of *Agaricus* (e. g. *Volvaria*, *Amanita*) the whole fungus is enclosed at first in a *volva* (*velum universale*), which on bursting falls away and is independent of the cuticle on the upper surface of the pileus, but remains attached to the base of the stem. Sometimes, as in *Amanita*, both forms of veil are found together. The stem is not always central, but is also found to be eccentric and even lateral, as in *Pleurotus*, in which it is usually very much suppressed. There are more esculent species of *Agaricini* than of any other group of Fungi. The species are usually terrestrial in habit.

Fig. 515.



The Mushroom (*Agaricus campestris*):—A. Fruit, showing the expansion from the *volva*, and the veil tearing away and leaving the annulus. B. Section of "gills," magnified 50 diameters. C. Basidia and spores from ditto, magn. 400 diam.

In the *Polyporei* the hymenium is spread over the cavity of tubes or pores, and is in some cases inferior and in others superior. The texture of the plants is, as a rule, more cartilaginous and woody than that of the *Agaricini*. The genus *Boletus* has the habit of an Agaric, and usually its central stem and texture. The hymenium is distinct from the hymenophore, from which the tubes are easily separated. The genus *Polyporus* is, on the other hand, different from the *Agaricini* in habit—the stem when present being usually lateral, and the texture of the whole often very woody. The hymenophore is not easily separated from the pores. In the resupinate forms the pores open upwards, and the habit of the fungus is crust-like. The species of this genus grow, as a rule, on stumps of trees and other woody substances.

The hymenium of the *Hydnacei* is inferior or amphigeous, and spread over teeth or spines, which are soft, usually of the shape of an awl, and distinct at the base. Some of the species are in the form of a stalked pileus with the teeth on the under surface, while others resemble the

resupinate forms of *Polyporei*. Several of the species are fleshy and edible, but others are of a corky texture.

In the Auricularini the hymenium is confluent with the hymenophore, which is even and very rarely veined. The habit is generally the same as in the Polyporei.

The hymenium of the *Clavarinei* is scarcely distinct from the hymenophore, and is amphigeous, and reaches to the apex of the plant, which is sometimes club-shaped, and sometimes in the form of spines usually growing together at the base. The surface is at first smooth, but becomes wrinkled afterwards. The plants are never incrusting nor leathery, but are usually at first gelatinous and afterwards horny. It is said that several species are esculent.

Suborder 3. Gasteromycetes.—Fungi forming roundish angiocarpous receptacles consisting of an outer layer or peridium enclosing masses of tissue on which are borne the hymenia. The spores are borne at the points of basidia, one basidium often producing as many as eight spores. The spores are liberated either by the simple bursting of the peridium, or by the development of particular masses of tissue.—Illustrative Genera: *Phallus*, L.; *Lycoperdon*, Tournef.; *Hymenogaster* Vitt.: *Nidularia*, Fr.

Structure and Life-history.—In *Phallus* the peridium resembles the universal volva of some Agarics in the way in which it envelopes the internal part of the receptacle, and also in its manner of bursting. Within the volva is a gelatinous stratum, and within that again the hymenium, which is very deliquescent and covered by an inner peridium. On the bursting of the peridium (or volva) the hymenium is elevated in a sort of pileus by a stalk, as in the volvate *Agaricini*. In *Clathrus*, an allied genus, the receptacle forms a globose network. In *Batarrea* there is also present a universal volva, and the hymenium is similarly elevated; but in *Lycoperdon*, *Hymenogaster*, *Nidularia*, &c., the bursting of the peridium sets free the spores without any such elevation, the hymenium remaining in the interior. The spores reproduce the mycelium, on which the same plant grows again without any intermediate stage as far as is known. The Puff-balls (*Lycoperdon*) and Stink-horns (*Phallus*) are typical of this Order.

ASCOMYCETES.

Diagnosis.—Fungi growing chiefly on the dead parts or remains of plants, more rarely on living plants or organic solutions. The spores of this Order are formed in *asci* by free cell-formation, and are distinguished by the name of *ascospores*. From the germinating ascospore there proceeds a mycelium consisting of densely branching hyphæ, which develops either within the host or spreads on its surface, and is sometimes short-lived, and sometimes persists for years. In most cases it is in a position to produce asexual reproductive organs—*conidia*, *stylospores*, and *spermatia*. The conidia are borne on conidiophores or special branches of the

mycelium, and the stylospores and spermatia are formed in special conceptacles (pycnidia and spermogonia respectively). The mycelium is extensively reproduced by these asexual organs, and in many species they are the only reproductive organs known. In all cases, however, in which the complete life-history has been followed the same mycelium has been found ultimately to produce sexual organs, and, as a result of the fertilization of these, a fructification, in the asci of which are formed the ascospores. This completes the cycle of generations.

This group is divided into the following Suborders :—

Suborder 1. DISCOMYCETES.—Fungi living on dead organic bodies, and forming on the branches of the mycelium sexual organs —the *carpogonium* (female) and the *pollinodium* (male). From the fertilized carpogonium, or, as it is then called, *ascogonium*, there arise the asci in which the ascospores are formed. The ascospores germinate and reproduce the mycelium. The hymenium is superficial, and on it are always the asci, and usually paraphyses, considered by some authors to be abortive asci.—Illustrative Genera: *Helvella*, L.; *Morchella*, Dill.; *Peziza*, Dill.; *Dermatia*, Fr.; *Patellaria*, Fr.; *Phacidium*, Fr.; *Stictis*, Pers.

Structure and Life-history.—The life-history of *Ascobolus*, as detailed by Janczewsky, is typical as regards Discomycetes generally. In it the *pollinodium* and the *carpogonium* consist each of a series of short crooked cells arising on neighbouring branches of the mycelium. The thin crooked cells of the pollinodium embrace the more remote end of the sausage-shaped carpogonium, and in this way the fertilization takes place. In consequence of fertilization, one of the cells in the middle of the carpogonium grows larger than the others, and becomes globular in shape; it is distinguished by the name of ascogonium. The ascogonium then sends out numerous hyphæ on which are borne the flask-shaped asci, and in them the ascospores, 8 in number. The hyphæ of the mycelium on which the sexual organs are borne produce by repeated cell-division a dense mass of pseudo-parenchyme, which surrounds the carpogonium and forms the sterile part of the fructification. The paraphyses which are borne on the same hyphæ with the asci are situated between the latter, and may serve, according to Boudier, to assist in some way the dehiscence of the asci; they are generally regarded, however, as abortive asci. The whole fructification is cup-shaped.

The sexuality was first discovered in the Ascomycetes by Professor de Bary in the case of *Peziza confluens*. The process of fertilization, &c., though differing in this case from that described above as occurring in *Ascobolus*, agrees in all essential details with it.

There are certain species of *Peziza* the mycelium of which forms conidia, and the unripe fruit is represented by a resting sclerotium. This has been observed by Prof. de Bary in *Peziza Fuckeliana*. In it the conidia are formed on the mycelium prior to the sclerotia, and reproduce the mycelium extensively. No sexual process has been observed in connexion

with the formation of the sclerotia, which consist of a dense mass of hyphæ enclosed by a black rind. If the sclerotia germinate shortly after their formation, the result is a mycelium which bears conidia again; but if germination is delayed for a month or two, a basin-shaped hymenium is formed, on which asci containing ascospores arise. This form of fructification is that commonly known as *Peziza Fuckeliana*.

The spermatia borne in the spermogonia have, until lately, been believed to be incapable of germination; but M. Cornu states that he has caused them to germinate and produce a mycelium like the conidia. In *Peziza* and the allied genera the whole fructification is basin-shaped, with the hymenium on the inner surface of the basin; but in other cases, e. g. *Morchella, Helvella, Spathularia, Geoglossum*, &c., it takes the form of clubs or stalked caps of considerable size with the hymenium on the outer surface. Our present knowledge of the processes of fertilization, &c., in the Discomycetes is the result of the labours chiefly of Tulasne, De Bary, and Janczewsky.

The species of *Morchella* and *Helvella* are, as a rule, esculent, but none of the other forms of Discomycetes have attained any reputation for this quality.

The genus *Gymnoascus* is an assemblage of small and very simple Ascomycetous Fungi growing on dung. Its mycelium begets numerous sexual organs, which, up to the time of fertilization, are (male and female) exactly alike. After fertilization the carpogonium divides into a series of cells, from which there grow out short, branched cells, on which the asci containing 8 spores are borne in abundance. The fructification is quite destitute of a covering. Though not agreeing with the general characteristics of the Discomycetes, it is yet more nearly akin to them than to any other forms of the Ascomycetes.

Suborder 2. ERYSIPHEÆ (fig. 1 B, p. 8.).—Fungi growing on living plants and dead organic bodies, and consisting of a mycelium which spreads on the surface of the host and sends into it numerous *haustoria*; forming small globular fruits with thin coverings, which enclose one or several asci springing from a carpogonium.—Illustrative Genera: *Erysiphe*, DC.; *Eurotium*, Lk.

Structure and Life-history.—The species of *Erysiphe* grow on the leaves and green stalks of Dicotyledons—more rarely on Monocotyledons. The mycelium ramifies densely on the surface of the host-plants, through the epidermis of which it sends down numerous haustoria, and is reproduced by conidia produced in series at the end of unbranched conidiophores. As in many Ascomycetous and other Fungi, the conidia are the only forms of reproductive organs known in certain species, and this has, in the case of *Erysiphe*, as in the others, been productive of confusion of genera. For example, *Erysiphe Tuckeri*, a vine disease, was long described as a species of *Oidium*. On the other hand, in many other species of *Erysiphe*, the sexually produced fructification is easily to be found either adhering to the mycelium threads or free. Both conidia and the sexually produced fruits are borne on the same mycelium. The car-

pogonium is surrounded by numerous pollinodia, and fertilization takes place in the same way as in the Discomycetes. In some species the fertilized carpogonium contains only one ascus of an ovoid shape, which encloses eight ascospores. In other species the carpogonium contains several asci.

The species of *Eurotium*, e. g. *E. repens* and *E.* (*Aspergillus*) *glaucus*, agree in the essential details of their life-history with those of *Erysiphe*. The mycelium is floccose, and may be found on the surface of the most varied dead organic bodies. First are formed conidia in great abundance in clusters at the apex of the conidiophores, and these reproduce the mycelium so plentifully, that this fact, when coupled with the easily satisfied requirements of the fungus in the matter of hosts, accounts for its exceedingly wide distribution. On the same mycelium there arise afterwards the sexual organs. The carpogonium is the end of a mycelial hypha closely wound up in the form of a corkscrew, and provided with several transverse septa—one to each turn of the screw. From the lowest turn there arise two tubes which grow up on the outside of the carpogonium; one grows more rapidly than the other, and reaches the top of the carpogonium, with which it conjugates. This is the pollinodium. Other cells then grow out from the bottom of both organs and envelop them. After fertilization the carpogonium divides into several cells, on the branches which proceed out of which the asci, containing 8 spores, arise. These ascospores germinate as in the other *Erysipheæ*, and produce a mycelium which bears first conidia, and again the sexually produced fructifications—perithecia.

Suborder 3. TUBERACEÆ (fig. 1 C, p. 8).—Fungi forming usually large subterraneous tuberous fruits, possessing a thick wall (*peridium*) of pseudo-parenchyme, enclosing a dense mass of hyphæ, among which the ascogenous threads form many asci imbedded in the sterile threads. The mycelium is usually very small in comparison with the fructification, and conidia are known only in the case of *Penicillium glaucum*.—Illustrative Genera: *Tuber*, Mich.; *Penicillium*, Link.

Structure and Life-history.—The mycelium of *Penicillium glaucum* grows on almost all organic substances, and produces long chains of conidia on erect conidiophores in such abundance as to account for their general presence in the air, and the appearance of the fungus on nearly every suitable and accessible host. It is only, however, in darkness that, like the other Tuberaceæ, the fruits are formed. It is well known that the conidia are not developed in darkness, and this formation of sexually produced fruits in that condition (recently discovered by Brefeld) is a further mark of the capacity of this fungus for distribution. The sexual organs resemble those of *Eurotium* (above described) so closely that a description is unnecessary; but the development of the fructification after the fertilization of the ascogonium is different from that of any other Ascomycete. Shortly stated, the ascogonium after it has begun to germinate is so hindered by the growth of the enveloping threads, that it is compelled to rest for some time in a sclerotioid state. When germination is induced, however, by artificial means, the ascogenous threads are seen

to force their way out and form asci, in each of which there are 8 ascospores. These spores germinate and produce a mycelium, which again bears conidia. The sclerotia also when kept so long that the ascogenous threads have lost the power of forming asci, germinate and form the usual conidia. The sclerotia are in structure so similar to the well-known fruits of the *Tuberaceæ* (Truffles), that, however, strong the resemblance of the sexual organs may be to those of *Eurotium*, they must be classed with the former. In no other species of *Tuberaceæ* have conidia been observed.

Suborder 4. PYRENOMYCETES.—Fungi growing usually on dead organic bodies and on living plants, and forming round or flask-shaped conceptacles (*perithecia*) with walls of pseudo-parenchyme, and containing long club-shaped asci, each of which produces (as a rule) 8 spores. The perithecium is in some cases open at first, but in others an opening is ultimately formed in the neck of the flask, through which the spores are emitted. (It is not yet clear whether this fructification be generally the result of sexuality or not.) When the ascospores germinate, they produce a mycelium on which are formed conidia, stylospores (in pycnidia), and spermatia (in spermogonia). In many species one or more of these organs are wanting, and in many others one or more of these are present and the perithecia wanting.—Illustrative Genera: *Claviceps*, Tul.; *Nectria*, Tod.; *Sphæria*, Hall; *Xylaria*, Hill; *Dichæna*, Fr.; *Venturia*, Fr.; *Stigmatea*, M.

Structure, &c.—In a number of species (e. g. the *Sphæriæ simplices*) the perithecia arise on a very fine mycelium, singly or in groups, and in such cases it seems to be probable (from Woronin's observations) that they are the result of a sexual act. In other cases, however (as in *Xylaria*), the perithecia are formed on large club- or basin-shaped stromata, consisting of dense masses of tissue. It is uncertain whether the stroma be merely a receptacle, or whether there takes place in it a sexual act which gives rise to the perithecia. The conidia are formed not only on the mycelium, but also on the stroma or even (as was seen to be the case in *Penicillium*) on the wall of the perithecium. Sometimes conidia and stylospores of two different forms occur in the same species. It has been suggested that the spermogonia and pycnidia are merely parasitic on the Pyrenomycetes; but this view has, in the case of the pycnidia, been recently disproved by the researches of Dr. Bauke, and in the case of the spermogonia by M. Cornu, who was the first to cause the spermatia to germinate and reproduce the mycelium. This Suborder, like the Discomycetes, includes a great number of forms, many of which seem to be only stages in the life-history of other plants, and which have received the names of distinct genera and species.

Suborder 5. LICHENES (figs. 516 & 517).—Fungi consisting of a thallus of densely interwoven hyphæ, sometimes forming pseudo-parenchyme, deriving their nourishment from minute Algæ

(formerly called *gonidia*) imbedded in the thallus (such as *Palmella*, *Nostoc*, &c.), and forming regular organs of fructification (apothecia) containing asci, in some cases known to be the result of a sexual process. There are formed also on the thallus *spermogonia* containing *spermatia* (the male organs, which have been proved in certain cases to fertilize a female organ called a *trichogyne*) and occasionally *pycnidia*. — Illustrative Genera: *Opegrapha*, Pers.; *Umbilicaria*, Hoffm.; *Verrucaria*, Pers.; *Endocarpon*, Hedw.; *Sphærophoron*, Pers.; *Cladonia*, Hoffm.; *Lecidia*, Ach.; *Stereocaulon*, Schreb.; *Parmelia*, Fr.; *Sticta*, Schreb.; *Cetraria*, Ach.; *Roccella*, DC.; *Ramalina*, Ach.; *Collema*, Ach.

Fig. 516.

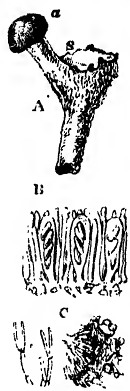


Fig. 517.

Fig. 516. A. Fertile branch of the thallus of *Sphærophoron coralloides*, with *a*, a perithecium, and *s*, spermogonia. B. Thecæ and paraphyses from the perithecium. C. Spermatia from the spermogonium.

Fig. 517. A. Branch of *Ramalina fraxinea*. B. A fragment with apothecia. C. A section of a fragment magnified, showing, *a*, apothecium, and *s*, spermogonia.

Structure and Life-history.—The parasitism of the fungal portion of the Lichen thallus is not of such a nature as to cause the death of the host alga, but the relations seem to be so equally balanced as to allow of the protracted mutual existence of both. To illustrate this and the life-history of the Lichenes two instances will perhaps be sufficient, both of which are from the recent researches of Dr. Stahl.

Sexuality is not known to exist generally in the Lichenes; but since it has been established in the *Collemaceæ* (an important subdivision) we may fairly conclude that the matter only wants investigation to bring more instances to light. In this subdivision the minute male cells or spermatia are formed within closed receptacles called spermogonia, and, unendowed with the power of motion, reach the female organs by the conduction of water (rain, &c.). The female organs or trichogynes may be said to be composed of three parts according to their function:—(1) a unicellular organ of conception, (2) a conductive canal, (3) an ascogonium in the form of coils, also composed of several cells which, when fertilized, give rise to the spores. The point of the trichogyne is protruded through the surface of the thallus, in which the rest of the organ is imbedded, and the spermatia coming in contact with it, the contents become amalgamated with the result of fertilization. The first result of the fertilization is seen in the increasing size of the cells of the ascogonium, and also an increase in their number by the formation of transverse septa. The paraphyses

then spring from the primitive coil of the ascogonium and increase in number with the formation of the hymenium, on which ultimately the asci arise from the ascogenous threads. The production of spores by the asci terminates the generation.

As to the relations between the parasite and host, the following instance will prove illustrative. The Algæ embedded in the host received the name of *gonidia* before their nature was truly understood, and it was generally supposed that they were special organs. A smaller form of gonidia, called the hymenial gonidia, was found to occur also in the empty spaces of the apothecia of many Lichens. They are the offspring of the true gonidia by division, and are carried up in the hymenium by the growth of the hyphæ. They are cast out of the apothecia along with the spores, and the spores on germinating envelope with their germ-tubes the hymenial gonidia, which increase in size and become the thallus-gonidia of the new lichen. This has been observed in *Dermatocarpon Schæreri* and *Polyblastia rugulosa* by Dr. Stahl. Beside the *Dermatocarpon* there grows a species of *Thelidium* the gonidia of which are the same species of alga (of the genus *Pleurococcus*) as those of the genus *Dermatocarpon*. If the spores only of the *Thelidium* be brought together with no other organisms than the hymenial gonidia of the *Dermatocarpon*, the thallus of the *Thelidium* with the characteristic fructification may be obtained on a suitable substratum, thus proving that the same species of gonidia can nourish two Fungi of even different genera. It must not be assumed that the above history of the gonidia is true of all Lichens under all circumstances, since no doubt the great majority of Lichens find their hosts in a more accidental fashion. The gonidia reproduce themselves exactly like the free individual Algæ of the same species or genus.

Distribution.—Lichens grow mostly in exposed situations, such as on rocks, walls, trees, &c. in all parts of the globe. They form a very large proportion of the entire vegetation in the higher regions of mountains and in polar latitudes. The thallus has usually a dry, dead-looking aspect (though sometimes soft and pulpy), and is of a foliaceous or scaly and crustaceous form. It varies much in size.

Qualities and Uses.—Many Lichens are very nutritious; a number of them yield valuable dyes; some are medicinal, others aromatic. Among the more important nutritious kinds are:—*Cladonia rangiferina*, "Reindeer Moss;" *Cetraria islandica*, Iceland Moss, and *C. nivalis*; *Umbilicaria* (various species), constituting "*Tripe-de-roche*" of the North-American hunters; *Lecanora esculenta* (Tartary) and *L. affinis*, *Sticta pulmonaria*, &c. From *Lecanora tartarea*, the purple dye called Cudbear is obtained; *Parmelia parietina*, common on walls and roofs, gives a yellow colour; *Roccella tinctoria* (Mediterranean and Cape-Verd Islands, &c.), *R. fuciformis* (Madeira, Angola, Madagascar, S. America), and *R. hypomecha* are Orchil-weeds, from which the dyeing material Orchil or Orchel is obtained—*litmus* being obtained from these and other species of *Roccella*. Some species contain a considerable quantity of oxalate of lime in the form of crystals.

MYXOMYCETES.

When young, naked, mobile, in consequence of which the masses of plasmodium have a changing form. These masses, at the time of fructification, sometimes dividing themselves into single parts, are transformed into motionless fruits. Fruit either irregular in form (*plasmodiocarp*) or regular (*sporangium*). Sporangia, through fusion and union, produce now and then compound fruits (*Æthalium*) usually of considerable dimensions, of regular or irregular form, naked, or covered with a common coat (*cortex*). Spores produced within the fruit through free cell-formation, or on the surface through division. The contents of the spores at the time of germination give rise to either at first a naked zoospore, provided with a nucleus, a cramped vacuole, and long cilia, or to an amœboid. These zoospores or amœbæ, flowing together in masses, give rise to mobile plasmodia. (*Rostafinski.*)—Illustrative Genera: *Physarum*, Pers.; *Didymium*, Schrad.; *Spumaria*, Pers.; *Stemonitis*, Gled.; *Amaurochæte*, R.; *Dictyostelium*, Bref.; *Cribraria*, Pers.; *Reticularia*, Bull.; *Trichia*, Hall; *Lycogala*, Mich.

Structure and Life-history.—The Myxomycetes present in the course of their life phenomena so entirely different from those occurring in other Thallophytes, that it has, with much reason, been proposed to separate them from this great group, and to place them among animal organisms, to which at least one stage of their existence shows the greatest similarity. The mobile or plasmodium stage resembles very strongly the mobile *amœbæ*, of the animal qualities of which no doubt has been entertained; but the fructification is so little like the "encysting" of these animals, or any other process in animal life, and moreover is so fungal in its nature, that this proposition has not been generally accepted. Not only the habit of life, but even the processes of nutrition of the plasmodium stage are animal.—These organisms are to be found in damp situations, on rotting wood, leaves, &c.

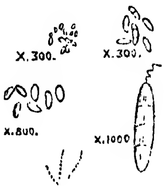
The whole of this subject is so large and many-sided (and its relative importance here is so small), that for details of the life-history of these organisms the student must be referred to De Bary's 'Mycetozoa,' and for their systematic disposition to Rostafinski's Monograph of the Order. Incidental reference will be found to them under the head of Physiology.

SCHIZOMYCETES.

The *Schizomycetes*, which are the lowest forms of life known, inhabit fluids which contain organic matter. The majority consist of extremely minute cells which neither in their membranes nor contents exhibit any marked characteristics. They are usually present in great abundance wherever putrifying organic matter is found. Among them are included such forms as *Bacteria*, *Sarcinæ*, *Vibriones*, *Spirilla*, some of which show a slightly higher organiza-

tion than others in the possession of cilia by which motion is effected. They usually multiply by simple segmentation; but in such cases as *Bacillus* an apparent reproduction by means of sporules has been observed. It is probable that some of these organisms are stages

Fig. 518. Fig. 519.



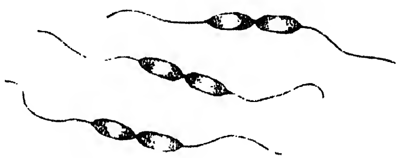


Fig. 518. Various species of *Bacterium*.
Fig. 519. *Bacterium termo*, magn 2400.

of some more perfect plant. The small Schizomycetes called *Bacteria* are often found growing on the mucous surfaces of living bodies and on wounds, &c.; and on this subject there has arisen an extensive literature, which is of more medical than botanical interest; and there is no doubt that, in a great multitude of cases, the observers have mistaken the products of the decomposition of organic bodies and crystalline precipitations of an inorganic nature for *Bacteria*. Whether the *Bacteria* are the real causes of fermentation and of various diseases, or whether they are merely concomitants of those processes, is a debated point upon which it is impossible to enter here.

Allied to the Schizomycetes, though of a higher organization, is the genus *Saccharomyces* (or *Torula*), to which the Yeast-plant belongs. The Yeast-plant consists of single, roundish minute cells of greater size than those occurring in the Schizomycetes. It inhabits fluids which contain sugar, in which it excites alcoholic fermentation. The cells contain true protoplasm, which can easily be recognized as such, and in which vacuoles are usually to be found. They multiply by simple exogenous or endogenous segmentation (fig. 1 A, p. 8, fig. 587, p. 552).

The life-history of the Yeast-plant is further treated of under the head of Nutrition in Cellular Plants, to which the student is referred (see p. 552.)

PART III.

PHYSIOLOGY

CHAPTER I.

PHYSIOLOGICAL ANATOMY OF PLANTS.

Sect. 1. The Structure of Plants.

The Physiology of Plants is that department of Botany which treats of the phenomena of the *Life* of Plants, as manifested in a series of changes taking place in the diverse organs of which each plant is composed. These organs, as we have already seen (Morphology, Chap. I.), are not simply fragments, combining to increase the bulk of the object (their size alone having no definite relation to that of the entire plant), but they are *instruments*, variously occupied in performing the different functions, the continuous operation of which indicates the existence of what we call Life. For morphological purposes it is best to use the word "part" or "member" without reference to physiological function, which may be different in parts of the same morphological nature. For physiological purposes the term *organ* is now employed.

The external characters of the parts of plants, generally, have been described in the First Part of this work, and an indication of their functions has been conveyed by their classification under the heads of Vegetative and Reproductive Organs. But the object of the Morphological chapters was to point out the conditions and relations of Form, as produced by the external shapes of the individual organs and their modes of combination. Here we have to examine the phenomena of Vitality, as displayed in the changes they present in the course of the Development, Growth, and Multiplication of Plants.

The physiological Organs of plants are themselves composed of a number of parts, which again exhibit a kind of completeness of their own, and a relation to the organs analogous to the relation

of the latter to the entire plant. These ultimate parts of organic bodies, arrived at long before we reach the limits of the possible mechanical divisibility of the objects, constitute the "atoms," physiologically speaking, of plants, and are called the *Elementary Organs.*

Under certain limitations, we may compare a plant, or an organ of a plant, to a crystal. Each has its definite character by which it is possible to distinguish it from any other object. But we might pulverize the crystal, and yet any one fragment of sufficient size for operation would display to the analyst all the chemical qualities of the entire crystal; and if we dissolved such a fragment and crystallized it upon a slip of glass, we should perceive by means of the microscope that it solidified into a miniature representation of the original crystal; moreover, if we then collected all the fragments and dissolved them, we might by careful evaporation reproduce a crystal exactly like that from which we started. In Vegetables (as in Animals) the case is entirely different. When we cut a plant in pieces, the parts differ not only in form but in structure, and bear no longer any recognizable relation to each other; we cannot reproduce the plant from them, and even the chemical examination of different fragments may give most diverse results—ultimate analysis alone, by which they are resolved into their mineral elements, arriving at the detection of a common bond among them, that of being formed of compounds which we only meet with in *organic matters.* Above all, in the act of subdivision, although this may be carried to a high degree in plants without destroying life (even sometimes within the limit of single organs), beyond a certain point it results in the annihilation of the especial force, the organizing or vital principle, by which the organs were made to combine their activity to produce the distinctive character as an independent individual object.

The diversities of form and consistence of the Elementary Organs give rise to all the differences of physical condition in the organs of vegetation and reproduction; and all those changes which collectively constitute the life of plants depend on the combination of a multitude of minor operations which have their seat in the elementary organs, singly or as combined into tissues. The study of the Elementary Anatomy is therefore the only secure foundation upon which to build the Physiology of Plants.

Cells, Protoplasm.—The *elementary organs* of plants are all referable to one primary type, which is not only recognizable through a comparison of the fully developed modifications, but is found to be the form in which all originate. This fundamental organ of vegetable structure is called a *Cell*, and may be defined as a closed sac composed of solid membrane, called the *cell-wall*, and filled with fluid, *cell-sap*, and semifluid matter, called *protoplasm.*

It must not, however, be overlooked that living plants and living parts of plants can exist, at least for a time, without any bounding cell-membrane. The perfect cell is taken, in a morphological sense,

as the fundamental unit for convenience' sake, and because it presents a definite form; it is not, however, to be regarded as the ultimate structural unit, because detached fragments of it are capable of independent existence under certain circumstances, and the protoplasm, in which in all cases the whole vital activity centres, is capable of living and moving without a cell-wall.

Cell-contents.—The cell is the elementary organ of vegetable structure; but it is not the smallest or most simple definite form in which organic matter may exist in plants. In the contents of cells we find *granules* of various kinds &c., and also *fibres*; the former, however, are not direct constituents of tissues, but occur only *among the contents* of cells, as more or less transitory conditions of assimilated matter; while the latter merely form parts of the structure of the cell-membrane.

Uni- and Multicellular Plants.—Plants of the lowest organization consist of the ultimate or elementary organs in their simplest forms, and may even be so simple as to consist of a single elementary organ or cell (figs. 503 E, 513). A step higher, we find plants composed of a few cells connected together into a definitely arranged group in their earlier period of existence, and subsequently separating entirely into the constituent cells, each of which lays the foundation of a new colony.

Tissues.—By far the greater part of the species of plants are composed of an indefinite number of cells permanently combined together and forming what are termed the *tissues*. If the cells entering into the composition of a tissue are essentially alike, they form a *simple tissue*; if cells which have undergone modifications which give them an essentially diverse character are combined in an anatomically well-defined tissue, this is called a *compound tissue.*

In the Algæ, especially the simpler membranous or filamentous forms, we may readily see the uniformity of the character of the cells throughout the *thallus* (p. 435); the same uniformity prevails through the cells of such tissues as the pith of Dicotyledonous stems, &c. But if we examine the wood surrounding this pith, or even the ribs running into the leaves, we find a variety of conditions of the elementary organs within the well-defined limits of these portions of woody tissue.

Cellular tissue.—The *simple tissues* of plants are divisible again into two primary groups, according to the mode of union of the constituent cells. In proper *Cellular Tissues* the cells, however firmly coherent, are only *in contact* by their walls, which form a persistent boundary between them. In a series of tissues most extensively developed in plants of high organization, the cells enter into closer relation, becoming confluent by the absorption of their contiguous surfaces, and thus converted into more or less extensive

tubular bodies, which, in their various conditions, form what are called the *ducts* and *vessels* of plants. These constitute the *Vascular Tissues.*

Vascular tissues.—What are called the *vessels* of plants are really compound elementary organs; but it is not requisite to enter into more minute distinctions here, since the phenomena of *fusion* of cells into such compound organs are not very varied in plants, and in all cases the composition of the structure from a number of distinct cells is very evident.

The tissues, simple and compound, enter into the composition of the Organs of Vegetation and Reproduction of Plants upon a certain general plan for any particular kind of organ, but under specially modified arrangements, referable to a progressive series of types, in the several large Classes of the Vegetable Kingdom.

Sect. 2. The Cell.

Form.—The shape and sizes of the cells of plants are determined by causes of two kinds, namely:—their own laws of growth, which are inborn and hereditary; and the favourable or obstructive influences which bear upon their development in each particular case. As a general statement, it may be said that the primary form of the Vegetable Cell is that of a sphere, and that deviations from that type are more or less attributable to secondary influences, arising from the connexion of cells in coherent groups.

The spherical form is usually found in cells developed freely, *i. e.* not arising from mere subdivision of a preexisting cell. Thus we find embryonary cells and endosperm-cells in the embryo-sac of Phanerogamia, the spores of some Cryptogamia, together with many of the lower plants composed of one or few cells only, such as those of growing Yeast (fig. 587, p. 552), &c., presenting the spherical as the original form. But by far the most frequently occurring spherical cells, such as many pollen-grains, spores, those in the pith of young shoots of Dicotyledons, of the pulp of fruit, &c., assume this form subsequently to the earliest stage of development, being placed in circumstances which allow them to expand freely according to their natural tendency.

The above general statement is subject to certain important exceptions, in which deviation from the typical form exists without any interference with the development of the cell according to its own laws; these are met with principally in the lower cellular plants, especially the Unicellular Algæ, in which we find single free cells assuming the most varied but specifically determinate forms.

Examples of this are offered not only by the *Desmidieæ*, but by the more unequivocally vegetable *Vaucheriæ*, *Botrydium* (fig. 503, E), and others.

The interfering influences above referred to are of two principal kinds, namely:—special directions assumed in the development, in obedience to

laws regulating the structure of the organism, or of the tissue, of which the cell forms part, *e. g.* unequal growth in particular portions; and obstruction to the possibility of expansion in certain directions, from the pressure of surrounding cells.

These influences are very fruitful in producing variety of form. The first kind is the most important, and determines the general form of the cell: the second in most cases affects merely the shape of its external

Fig. 520.

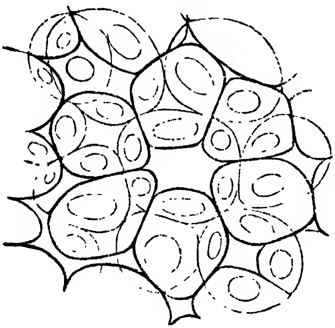


Fig. 521.

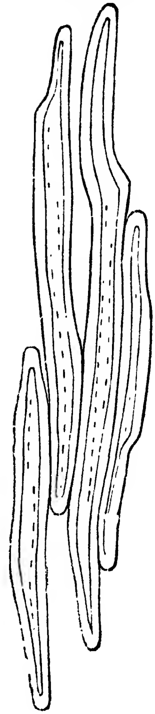


Fig. 522.

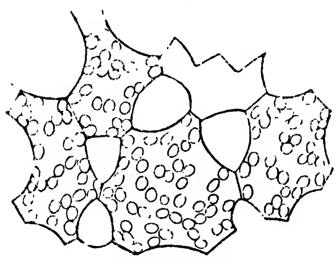


Fig. 520. Merenchymatous cells of the rind of *Euphorbia canariensis*. Magn. 100 diam.
Fig. 521. Liber-cells of *Cocos botryophora*. Magn. 50 diam.
Fig. 522. Parenchymatous cells from the leaf of *Orchis mascula*. Magn. 200 diam.

surface. The form of the cells of fully developed tissues is usually the result of both kinds of influence combined.

In cells existing in combination we find three principal classes of forms, referable purely to the influence of the law of development:—(1) the *spheroidal*, obedient to the fundamental type; (2) the *cylindrical*, in which there is a more or less considerable tendency to elongate in the direction

of a vertical axis; and (3) the *tabular*, in which there is an excess of development in the direction of the two transverse axes.

The *spheroidal* form presents every possible transition from the sphere (*Protococcus*, figs. 513, 514, *pollen* of *Passiflora*, *Hibiscus*, cells of cortical parenchyma, fig. 520, &c.), through the ellipsoidal (usual in longer or shorter forms in the subepidermal parenchyma of leaves), to the *fusiform* or *spindle-shape* (most abundant in the cells of wood and fibrous structure, fig. 521), and the truly *cylindrical*, either of moderate length (cells of Confervæ, fig. 512, &c.), or drawn out so as to become what is termed *filiform* (cotton

Fig. 523.

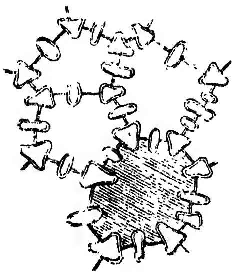


Fig. 524.

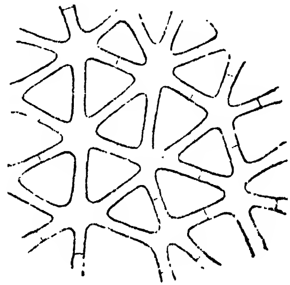


Fig. 525.

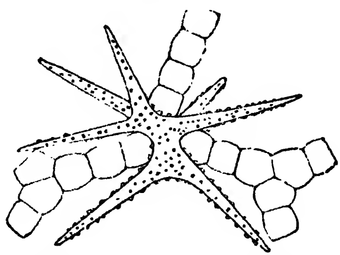


Fig. 523. Section of a septum of an air-canal in the petiole of *Sagittaria*. Magn. 300 diam.
Fig. 524. Stellate cellular tissue from the petiole of Rush. Magn. 300 diam.
Fig. 525. Stellate hair from the petiole of *Nymphæa advena*. Magn. 200 diam.

and other cellular hairs). The spheroidal form also passes gradually, especially in epidermal tissues, into the tabular form.

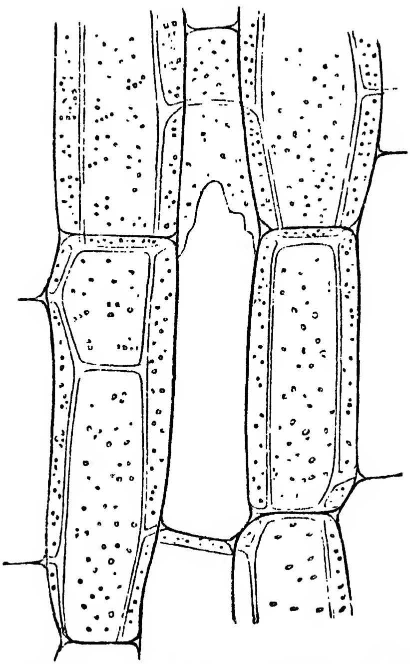
Modifications.—Secondary modifications of these forms arise chiefly either from partial cohesion in lax tissues, from irregular growth, or from pressure in densely packed tissues.

Thus the spheroidal form becomes, in lax tissues, an *irregular* spheroid in endless varieties (commonest of all in the parenchyma of leaves and rind of succulent stems), running out by degrees into lobed and finally

stellate forms, by exclusive development of the free surfaces while the contiguous cells remain attached at a few points, *e. g.* in cells of the parenchyma of leaves and leaf-stalks of many Monocotyledons (fig. 522), *Musa*, *Sagittaria* (fig. 523), &c., and above all in the cellular tissue of Rushes (fig. 524) and the stems of various aquatic plants. In the tissues of *Welwitschia*, as also in *Araucaria* and other Conifers, very large irregularly branching cells, covered with small crystals, may be seen: these are sometimes called *spicular cells*.

The mutual pressure of cells, commonly exerted in stems, in seeds, hard parts of fruits, &c., converts the spheroidal into *polygonal* forms, of

Fig. 526.



Cells of the pith of *Acanthus mollis*, seen in a vertical section. Magn. 200 diam.

which the more or less regular *dodecahedron* or *tetradecahedron*, giving an hexagonal section, and arising from equal pressure in all directions, is perhaps the commonest (pith of fully developed shoots of Dicotyledons, such as Elder, &c.), or *cubic*, found in woody fruits, &c. The cylindrical becomes under the same circumstances *prismatic*, either six-sided with flat ends, or with three rhombic faces at top and bottom, the common form of the cellular tissue of the stems of herbaceous stems (fig. 526), or 4-sided

with flat ends, as in the medullary rays of Dicotyledons, or with conical or oblique ends, the common form of wood-cells. Less frequent are the forms of spores and pollen-grains, sometimes only temporary, sometimes permanent, arising from the development of four cells by segmentation of a spherical parent cell; these sometimes appear of the form of quarters of an orange, sometimes as *tetrahedra*, the curved surface forming the base of the pyramid. In the tabular forms of the cell, the mutual pressure generally confirms an originally rectangular figure, the *tabular* cells of epidermis and cortical structure being usually of quadrangular or polyangular

Fig. 527.

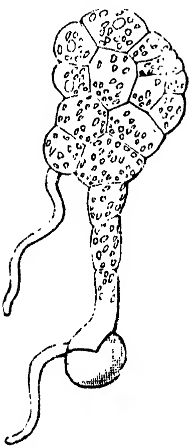


Fig. 528.

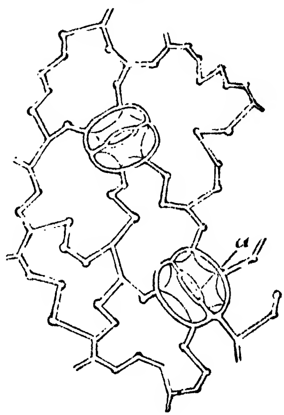


Fig. 527. Young prothallium developed from the spore of a Fern (*Pteris serrulata*). Magn. 200 diam.

Fig. 528. Epidermis of the lower surface of the leaf of *Helleborus fœtidus*, with stomata (*a*). Magn. 200 diam.

figure, flat above and below; but in these we have sometimes complication from expansion, under pressure, principally in certain directions, cells of the epidermis of many plants exhibiting side walls thrown into sinuosities following a particular pattern (fig. 528).

By far the great majority of cells in the higher plants originate in forms analogous to those produced by pressure, since they multiply by division, and the septa dividing two newly formed cells have ordinarily plane surfaces (fig. 527): a spherical cell forms two hemispherical cells, &c.; a prismatic cell dividing perpendicularly, two half-prisms, or, if horizontally, two superposed shorter prisms, &c. As a general rule these cells have a tendency to assume the spherical (or cylindrical) form in their earlier stages of growth, while the whole mass of tissue is lax; and if they are set free, as

in the case of spores, pollen, &c., they often become quite spherical. But if they form part of a permanent tissue, the expansion of the organ of which they form part stops at a certain point, before they cease to swell, and thus the mutual pressure comes to bear upon them and causes the production of plane surfaces.

We may trace this by making sections of a pith of a shoot of Elder from the growing point, or *punctum vegetationis*, downwards: at the point the nascent cells are squarish; lower down they have swollen into spherical, while when full-grown they are dodecahedral. The similar change from cylindrical to prismatic takes place in the *cambium-cells* of annual stem and shoots; but in succeeding years the cambium-cells formed by division of preexisting cells exhibit a rectangular outline first and last, only increasing in diameter, chiefly in a radial direction.

Dimensions.—The magnitude of cells is very varied. About $\frac{1}{400}$ of an inch may be taken as an average of the diameter of parenchyma-cells; the cylindrical cells are especially remarkable for the great length they often acquire as contrasted with their transverse diameters, and with the transverse and perpendicular diameters of other forms.

The larger cells of the pith of the Elder are about $\frac{1}{100}$ of an inch in diameter, but $\frac{1}{250}$ is to be regarded as a large diameter in parenchyma. On the other hand, the spores of Fungi afford examples of extremely minute dimensions, such as $\frac{1}{4000}$ to $\frac{1}{8000}$ of an inch. The cylindrical cells of wood are not uncommonly $\frac{1}{50}$ of an inch in length; liber-cells sometimes from $\frac{1}{12}$ to $\frac{1}{4}$ or $\frac{2}{3}$ of an inch (Flax). Hairs composed of one or more cylindrical cells, and the cylindrical cells of some of the Confervæ, especially *Vaucheria*, *Bryopsis*, &c., and *Chara*, also attain longitudinal dimensions to be measured in inches, while their diameter is estimated in hundredths of an inch.

The Cell-wall.—In all young cells the wall is of membranous nature, and in many cases it always retains this character. While young this membrane is freely permeable by water, elastic and flexible. As the cell-wall grows older it becomes altered in consistence and firmer, opposing a greater obstacle to the entrance of water into its substance, independently of any great increase of thickness, as we see in cork-cells: when it increases in thickness it may remain soft and flexible, or become very dense; but in such cases it generally remains tolerably freely permeable by water, even when most dense, while the softer kinds absorb water so readily that they swell up considerably when wetted.

Membrane of living cells always appears to contain water as an essential part, almost like the water of crystallization in hydrated salts. When dried, cells contract more or less; and many phenomena of bursting of fruits, sporanges, &c. are the result of the tearing down of weak regions of cellular tissue by the contraction of firmer tissues in drying. Cellular

tissues with soft thick membrane, like those of the Algæ &c., contract in drying so as to cause the shrivelling of the structure. All such tissues absorb water when wetted, and swell up again, but do not in all cases reassume their original flexibility. Cells of wood, liber, &c. also expand when wetted; but the expansion takes place in a direction transverse to their axes, and they usually contract in the longitudinal dimension as they swell laterally. Hence, although wood and fibrous structures swell in water, it is only in the direction *across* the *grain*, and cordage simultaneously *contracts* in the direction of the fibres.

Diluted sulphuric acid and alkaline solutions cause a swelling of the membrane of most cells, of which advantage is sometimes taken in woven fabrics to render the stuff closer in texture. By soaking in an alkaline solution, the single fibres are made to swell so as to come more completely into contact and fill up the interstices.

Primary, unaltered cell-membrane is colourless; subsequently it becomes coloured, usually of a tint of brown, apparently by infiltration of substances formed in the contents, since by boiling the membrane of old, deep-brown tissues with nitric acid, or with solution of potash, the colouring-matter may be extracted.

The original membrane of a newly formed cell is, as far as we have the means of perceiving it, a homogeneous layer of substance, the *porous* nature of which is, in most cases, only to be concluded from the fact of its permeability, no visible pores, except in exceptional cases, being revealed by the most perfect microscopes we possess.

It is important to note this homogeneity of the primary cell-wall, as the membrane almost always becomes marked with dots and spiral lines, indicating inequality of thickness, as it becomes thicker.

This primary membrane is apparently a secretion from the protoplasm, though by some it is looked on simply as a chemical precipitate. It appears to have the property of growing by what is called intussusception of molecules, since it expands to accommodate the increasing contents of the cell in cell-growth, without any indication of *structure* necessarily accompanying the expansion.

No better example of this can be mentioned than the growth of the pollen-tube of Phanerogamia, which sometimes acquires a length of 2 or more inches (*Cactus*) without ever departing from the homogeneous pellicular structure. Cell-membrane, however, may increase in size by expansion, as we see in the cell-division of *Œdogonium*, in which a thickened ring of accumulated cellulose is stretched out by the elongating cell and becomes a thin membranous coat to the latter.

Molecular structure.—The molecular structure of cell-membrane has been studied by Nägeli, who, from his researches on the constitution of the membrane of the starch-grain by means of polarized light, comes to

the conclusion that all organic substances are composed of *crystalline* molecules grouped in a definite manner. When dry the molecules are without interspaces; when moist, each molecule is surrounded by a thin film of water. Nägeli further supposes that each molecule is made up of a number of atoms, similar to or identical with the atoms of the chemist. The molecules are of different sizes; those portions of the structure richest in water have the smallest molecules. The molecules themselves are of the nature of crystals with two optic axes. It is possible that the extremely minute dots and striæ above mentioned may have some relations to this molecular structure.

Secondary Growths.—The walls of almost all cells soon exhibit a departure from the original simple condition, arising from the formation of new lamellæ, more or less resembling the primary membrane, all over, or over particular parts of, the inside of the primary membrane. These are distinguished as *secondary layers* (figs. 529, 530). They are of different densities, and they are usually separated one from the other by thin films of watery cell-sap. The consistence of these layers, and the mode in which they are disposed, produce the most important diversities of character of the walls of fully developed cells.

Fig. 529.

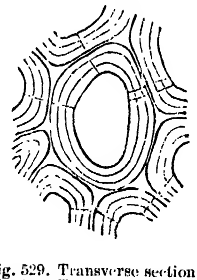


Fig. 530.

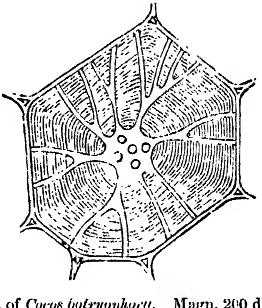


Fig. 529. Transverse section of liber-cells of *Cocos botryophora*. Magn. 200 diam.
Fig. 530. Transverse section of a thick-walled cell from the pith of *Hoya carnosa*. Magn. 500 diam.

The laminated condition of cell-membrane may be well observed in simple cellular structures by treating fragments of *Cladophora glomerata*, or other large Confervoid, with diluted sulphuric acid. The laminæ are very visible in cross sections of the cells of wood and liber after these have been boiled for a short time in nitric acid. These so-called layers are not successive depositions, but are formed like the cell-wall itself, of which, indeed, they are intrinsic portions, by intussusception of new particles alternately more or less dense. The term layer is therefore a misnomer, descriptive of an apparent and not of a real condition.

Gelatinous Layers.—Besides the primary membrane and the secondary formations, we find in certain cases a kind of envelope which has been variously explained by different authors. The filaments of some Confervoids (*Spirogyra*, fig. 512, A), of *Desmidium*, &c., the families of cells of *Palmelleæ* (figs. 504, 513) and *Nostochineæ*, are surrounded by a coat of gelatinous consistence outside the proper cell-membrane. This appears to be produced by the softening and swelling up of the parent cells (of many generations) of the cells which are surrounded by such envelopes.

Cuticular Layers.—Another layer is characteristic of many cell-membranes which are destined to protect the subjacent tissues, or their own contents, from the action of the atmosphere, namely those of epidermal cells and of pollen-grains and spores. These exhibit a superficial pellicle, of varied character as to thickness, texture, and marking, which pellicle appears subsequently to the first formation of the cell. This, like the gelatinous coat just described, is a structure altogether of secondary character, but is distinguished from the ordinary secondary layers of thickening by its position on the *outside* of the cell-wall.

It is still a moot question whether these pellicles are secreted by the primary membrane on the outside, or are formed by transformation of the outer laminæ of the primary membrane itself, whose place is then taken by some of the outer secondary layers. This subject will be more dwelt upon under the head of the *cuticle*.

Thickening Structure.—The secondary formations on the inside of the cell-membrane may (1) correspond in character to the primary wall, in which case the cell-wall is simply thickened by new lamellæ; or (2) the new layers applying themselves over the surface of the wall, leave certain parts bare, which appear as *dots* or *pits* of various forms when viewed from the inside (figs. 531, A, B); or (3) they are applied only over parts which form peculiar patterns upon the primary wall, and appear, when of sufficient thickness, like *fibres* adhering to it, spiral, annular, or connected into a kind of network.

Those secondary layers which resemble the primary wall, although evenly deposited, present in certain cases an appearance as though their molecules were arranged in a spiral order, since fine spiral streaks may sometimes be detected, after treating them with acids and by other means, and many of them are apt to tear in a spiral direction. The excessively delicate spiral marking here referred to (seen in liber-cells of *Vinca*, fig. 533, and most Apocynaceæ and Asclepiadaceæ, in wood-cells of *Pinus*, in the cell-membrane of *Hydrodictyon*, &c.) must not be confounded with a deceptive appearance, resembling a much coarser spiral striation, produced by treating the membranes of Confervæ, the paren-

chyma-cells of *Orchis*, *Cucurbita*, &c. with sulphuric acid, where the appearance often results from the irregular convolutions of the swollen lamellæ of the cell-wall.

Fig. 531 A.

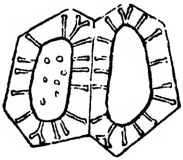


Fig. 531 B.

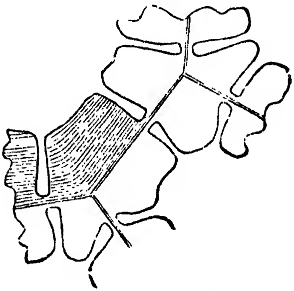


Fig. 531 A. Section of cells of the endosperm of a Sago-Palm. Magn. 200 diam.
Fig. 531 B. Laminated cell-walls of the cells in A. Magn. 500 diam.

The uniform kind of secondary layers are sometimes accumulated at one side (fig. 534), or in the angles of cells (fig. 535): thus they are much thicker on the side of epidermal cells next the air; and they fill up the angles of the cells of the fleshy endosperm of many seeds, the cells of the *collenchyma* found beneath the rind of Chenopodiaceæ, and the cells of the leaves of *Nymphæa*, of some Jungermanniaceæ, &c. There is reason to believe that, in some instances, the cell-wall thickens at certain seasons and becomes thinner at others; but this appearance may arise from an alternately swollen and contracted state, and not from absorption and redeposition.

The subject will be alluded to again under the heads of *epidermis* and *intercellular substance*.

Pitted Cells.—The deposits which leave spots of the primary membrane bare form what are called *pitted*, or, less properly, *porous* cells. They occur on the walls of most cells of the parenchymatous structures of the higher plants, in the form of round spots (fig. 526), where the still membranous cell-wall is thinner. In wood-cells, in liber-cells, and the greatly thickened cells of fleshy endosperms, hard seed-coats, &c., the formation of a great number of secondary layers upon the wall, always leaving those spots bare, converts the pits into canals running out from the contracted cavity to the primary wall (figs. 530, 531).

The marks are really always *pits* at first, as may be seen by colouring the cell-membrane with iodine. But in old wood-cells they appear some-

times to become holes, by the absorption of the primary membrane which formed a kind of diaphragm over the outer end.

These pitted markings may be circular, oval, or elongated transversely or more or less obliquely, so as to approach to the appearance of slits. Sometimes the later secondary growths do not extend quite to the edge

Fig. 532.

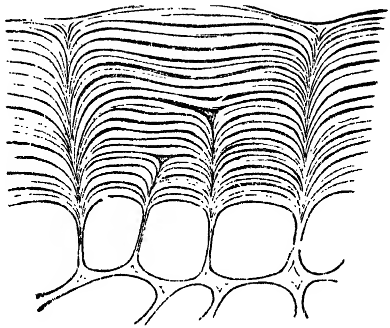


Fig. 533.

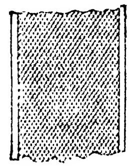


Fig. 535.

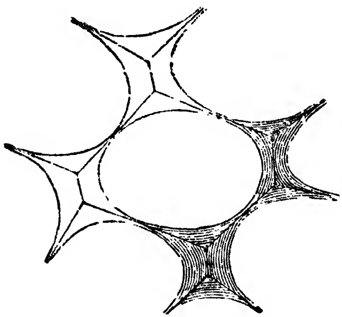


Fig. 536.

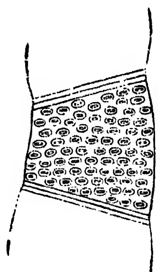
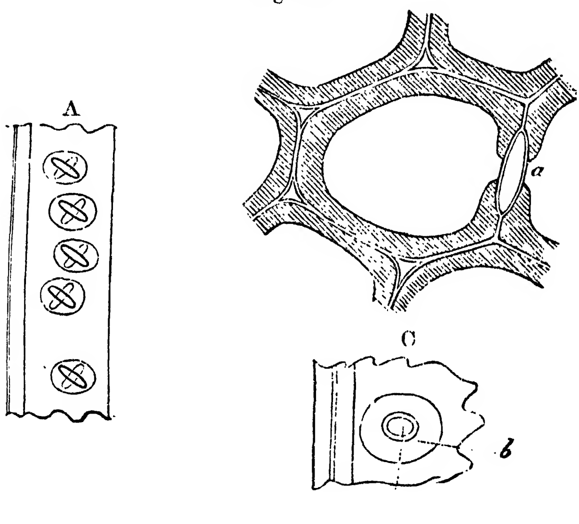


Fig. 532. Liber-cell of Periwinkle. Magn. 75 diam.
Fig. 533. Fragment of the cell in fig. 532, magnified 300 diam. (The spiral lines on the opposite side of the cell show through and cross.)
Fig. 534. Vertical section of epidermis of *Viscum album*, with many thickening layers. Magn. 400 diam.
Fig. 535. Transverse section of cells of the petiole of *Nymphæa alba*, showing the laminated wall. Magn. 500 diam.
Fig. 536. Fragment of a pitted duct of *Laurus sassafras*. Magn. 200 diam.

of the aperture in the earlier layers, and the successive layers may so retreat from this edge that the canal becomes at length funnel-shaped; in this case the pit, when seen in front, presents a double outline, one corresponding to the outer end, the other to the inner and wider end (fig. 536).

Bordered Pits.—This condition may be further complicated by the existence of a lenticular depression between the contiguous walls of pitted cells, as in the wood of Coniferæ (fig. 537). The outline of this depression gives the appearance of a circle surrounding the central pit—the circle being due to the greater thickness of secondary growth in that situation. Schacht, however, asserts that the pit is a real perforation, and, further, that in the very young condition the lenticular cavity between two adjacent cells is divided into two compartments by a thin longitudinal parti-

Fig. 537.



Pits or "Glands" of Coniferæ.

A. Part of a wood-cell of *Ginkgo biloba*, in vertical section. Magn. 500 diam. B. Transverse section of a wood-cell of *Pinus Pinea*: *a*, a bordered pit or "gland." Magn. 1000 diam. C. Fragment of the wall of a wood-cell of *Pinus Pinea*, with a bordered pit or "gland:" *a*, the pit; *b*, the large ring, caused by the lenticular interspace (*a*). Magn. 1000 diam.

tion, which is the primary deposit of the two cells. The lenticular cavity is formed by the resorption of this deposit, and a communication established between the two adjacent cells. These areolated pits (or *maculæ*, as Schacht calls them) are not, as was once supposed, confined to the Coniferæ; but they are universally found throughout that group with a regularity of disposition and constancy of occurrence not known elsewhere.

Lattice or Clathrate Cells, Sieve disks.—A further complication of the pitted structure has been described by Von Mohl as occurring in the *vasa propria* of the vascular bundles of Monocotyledons, and in the thin-walled cells, layers of which alternate

with the long woody fibres in the liber of Dicotyledons. In these cells, which that author calls "latticed" or "clathrate" cells, the membrane which forms the diaphragm closing large pits is marked with an excessively delicate network, apparently formed of fibres applied upon the primary membrane, and generally perforated. This occurs not only in the pits of the side-walls, but in those which are found on the septa between cells standing one above another, and which constitute the *sieve disks* of the Germans, the said disks being covered on one side with a thick hyaline structureless perforated plate, not coloured blue by iodine, and whose nature and functions are at present unknown.

Spiral Deposits.—The "fibrous" secondary layers may present the form of a single spiral band, running from one end of the cell to the other, and with the turns of the spire quite close or more or less distant (fig. 538); or the spiral band may be double,

Fig. 538.

Fig. 540.

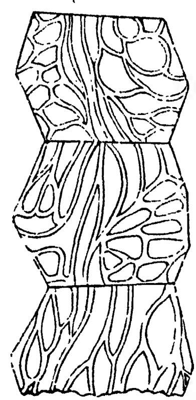


Fig. 539.

Fig. 538. Cell from the sporangium of *Equisetum arvense*. Magn. 250 diam.
Fig. 539. Cells from the sporangium of *Marchantia polymorpha*. Magn. 250 diam.
Fig. 540. Cells from the leaf of *Sanseviera guineensis*. Magn. 400 diam.

triple, or even consist of six or more parallel bands. Very often these spiral secondary deposits are sufficiently elastic to allow of their being stretched out, the comparatively thin primary membrane to which they adhere giving way at the interstices.

In the cells of the coat of the seed of *Collomia*, the primary membrane becomes, during the ripening of the seed, converted into a substance which softens and swells up in water; so that when this structure is wetted, the spiral fibre springs out, opening its coils widely like a wire spring.

The *annular* thickenings (fig. 539) are less common than the spiral, but occur sometimes in the same cell, and also in association with the next kind, the reticulated. The rings are generally at some little distance apart.

The *reticulated* secondary layers may be uniform over the wall of the cell, or irregular (fig. 540), which is more frequent, since the ordinary cause of the reticulated appearance is the formation of vertical connecting bars between rings or spiral coils at the angles of the cells; when this occurs very regularly, a ladder-like arrangement results, giving what is called the *scalariform* structure, especially frequent in the vascular structure of Ferns (fig. 541).

Fig. 541.

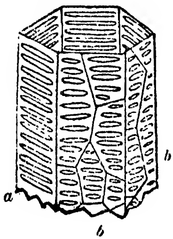


Fig. 542.

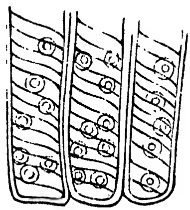


Fig. 541. Fragment of a scalariform vessel of a Tree Fern: *a*, walls in contact with other vessels: *b*, *b*, walls in contact with cells. Magn. 200 diam.
Fig. 542. Wood-cells of Yew; vertical section. Magn. 300 diam.

The connecting bars of the reticulated and scalariform cells must not be supposed to originate after the rings or spirals; they are contemporaneously developed; and the diversities in the closeness of the coils of cells are likewise original peculiarities of the deposits. The statement that the turns of spiral coils are opened by longitudinal growth of the primary membrane to which they adhere seems to be founded on speculative notions.

The spiral structure of secondary deposits is beautifully seen in the elaters of *Jungermannia* and *Marchantia*, in the cells of the aërial roots of epiphytic Orchids, in the cells of the wood of Cactaceæ, and in the spiral vessels of the veins of the leaves and leaf-stalks of Monocotyledonous plants, such as the Hyacinth, Narcissus, *Musa* (which presents as many as 20 parallel bands), shoots of Elder, leaf-stalks of garden Rhubarb, Strawberries, &c., also in the petals of delicately organized flowers. Annular cells are well seen in the sporanges of *Marchantia* and other Liverworts, and in many of the structures just mentioned with spiral and reticulated cells.

Scalariform Tissue.—The scalariform marking is most regular in Ferns, and approaches very nearly to the more regular forms of the thickening above described, so that the spiral-fibrous and the dotted forms appear as the extremes of an analogous kind of structure.

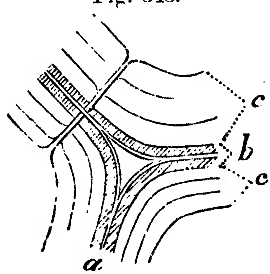
In many wood-cells, especially in root-structures, the reticulated or scalariform cells have the meshes so small that they become in fact pitted cells.

Tertiary Layers.—In some cells both kinds of thickening occur, so that it is convenient to distinguish *tertiary* growths. In the wood-cells of the Yew (fig. 542), of the Lime, and other plants the secondary layers are pitted, and a tertiary growth subsequently appears in the form of a spiral fibre.

The pits on the walls of contiguous cells correspond, and they do not generally occur opposite intercellular spaces, or on the outside of epidermal cells; but exceptions occur to both these rules, to the latter especially in the leaves of *Cycas*. The first rule has much influence on the marking of the large cells forming part of *ducts*, which are often in contact with several cells, one above another, and with parenchyma-cells, other ducts, or with intercellular spaces, on different sides. In the wood-cells of Conifers, the peculiar bordered pits occur only on the sides parallel to the medullary rays, not on the internal and external walls.

Cellulose, &c.—Cell-membranes, including the secondary layers, are composed of the substance called *cellulose*, which is one of a class of organic compounds intimately connected as regards chemical constitution, but presenting remarkable physical differences. Of these compounds the most important are:—*sugar* and *dextrine*, soluble in cold water, and occurring in solution in the cell-sap; *starch*, insoluble in cold, but softening and swelling into a mucilage in boiling water, and found in the form of granules in the cell-contents; and *cellulose*, insoluble in cold or boiling water, alcohol or ether, obstinately resisting the action of alkaline solutions, but soluble in strong sulphuric acid, and forming the permanent solid parts of vegetable structure. This cellulose is supposed to be derived from one or other of the materials above mentioned.

Fig. 543.



Wall of the cells of the liber of *Cocos*: *a*, primary membrane; *b*, oldest secondary layers; *c*, more recent secondary layers; the layers marked *b* are strongly incrusted. Magn. 600 diam.

Cell-membranes, originally composed of pure cellulose, undergo changes at subsequent periods which alter, in a marked manner, their behaviour towards chemical reagents; and it is not at present certainly ascertained what is the real cause of the series of modifications which they present. If we compare the membrane of a nascent cell, of thick-walled parenchyma, the solid and often dark-coloured walls of the cells of old heart-wood, of liber-cells, the very resistant membranes of corky tissues, and the layers of gelatinous or cartilaginous consistence so abundantly developed in the larger Algæ, we meet with extremely different characteristics, as to the explanation of

which different views are entertained. On the one hand it is said that the cellulose produced in the formation of the original membrane or layer of thickening becomes gradually converted into different but related chemical compounds; on the other, that the cellulose layers become impregnated by foreign substances, gradually infused into them from the fluid contents, such substances being distinguished by the name of *incrusting* matters (fig. 543). A third view is that of Frémy, who considers that there are several kinds or modifications of cellulose, and, moreover, that those vegetable structures formerly considered to be made up exclusively of cellulose contain matters of a different chemical composition.

Action of Reagents on Cellulose.—Cellulose, as found in the organized condition of cell-membrane, appears to behave somewhat differently to chemical reagents according to the state of aggregation of its particles (that is to say, its density); for nascent cell-membranes will in many cases assume a violet or even a blue colour when treated with a strong solution of iodine and washed with water, like starch. The same is the case with some of the semigelatinous layers of thickening met with in the endosperm or cotyledons of certain seeds (called *amyloid*), and, moreover, in the cell-structures generally which have been treated in the way described below, to remove the so-called "incrusting matters." But, as a general rule, cellulose does not take a blue colour with aqueous solution of iodine, unless some other agent, especially sulphuric acid, be applied at the same time. A solution of iodine in zinc chloride brings out a blue colour in fully developed cell-membranes, still more readily than the sulphuric acid with iodine. These reagents readily affect newly formed tissues in general; and the more delicate kinds of cellular tissues are permanently sensitive to them. But after a time the thicker cell-membranes, and especially those of woody tissues, the cartilaginous structures, and the tissue of epidermis and bark, no longer become blue, but only yellow or brown, with the above reagents; and it is the real cause of this alteration which is the subject of the difference of opinion above referred to. Anilin and sulphuric acid stain the lignified cells yellow *.

By maceration for several hours, or boiling for a minute or two, in nitric acid for woody and cartilaginous tissues or in strong solution of potash for epidermal and corky tissues, bringing the cells to a point where they still exhibit all their structure, but are bleached and softened, then washing

* The iodide solution consists of 1 grain of iodine, 3 grains of potassic iodide, and 1 ounce of distilled water. The sulphuric acid is of the strength of three parts acid to one of water. The preparation to be examined is first moistened with a drop of the iodine solution, which is then wiped off with a brush or piece of blotting-paper, and a drop of the acid is then placed on the preparation, which is covered with thin glass in the usual way. Schulze's solution is made by dissolving an excess of metallic zinc in strong hydrochloric acid, allowing the solution to evaporate over a spirit-lamp to the consistence of syrup, the zinc being kept constantly added if necessary. To the now colourless syrup is added as much potassic iodide as it will take up. The advantage of Schulze's solution is that it does not destroy the tissues, acts more speedily, and is less injurious to the microscope should it happen to come into contact with it.

them with water and applying iodine, a blue colour is produced like that appearing in nascent cellulose or in tolerably new tissues under the influence of sulphuric acid.

It remains to be ascertained whether these processes alter the composition of the cell-membranes, or merely remove infiltrated matters of nitrogenous composition. The latter view is supported by the fact that, in imperfectly prepared objects, some of the more resisting layers appear *green*, which would seem to result from an optical combination of the blue of the cellulose with the yellow of an infiltrated matter. At the same time it must be noticed that the cellulose is brought into a condition approaching that of starch, only normal in nascent membranes and in the semisolid deposits of "amyloid" above mentioned. Frémy, as above stated, considers that there are other substances besides cellulose entering into the composition of vegetable cell-walls. *True cellulose* forms the cell-wall of the cellular tissue of bark, fruits, roots, &c., and is soluble in ammoniacal copper oxide, made by dissolving copper filings in caustic ammonia. *Paracellulose* is found in the cells of the pith, the epidermis, the medullary rays, &c.; it is soluble in the copper solution, but only after special treatment. *Fibrose* is the constituent of the wood-cells, and is insoluble in the copper solution, except after special treatment, but soluble in strong sulphuric acid. *Vasculose*, the substance of which vessels are formed, is insoluble in hydrochloric and sulphuric acids and in the copper solutions, but soluble in boiling caustic potash. It is coloured by anilin with a little sulphuric acid.

Inorganic Constituents.—Cell-membrane in most cases contains a certain amount of inorganic matter; but this is probably attributable in general to its being saturated with the watery cell-sap, in which various salts exist in solution. In particular cases, however, there is a special deposition of inorganic substance in the walls of cells—as, for instance, in the Grasses and the Equisetaceæ, and the Cane-Palms (*Calamus*), where the epidermal structures are so loaded with *silex* that they not only acquire a hard texture, rendering them harsh to the touch, but, when the organic matter is destroyed by burning, a complete skeleton of the tissue remains, entirely formed of silex. The siliceous coats of the *Diatomeæ* afford another striking example.

It is not yet clearly made out whether the silex is here deposited in a layer upon the cell-membrane, or interpenetrates its substance; but the latter is probably the real state of the case. The pericarp of some plants, as *Lithospermum*, contains lime, in what form it is not certain; but the calcium carbonate incrusting the cells of many species of *Chara* is clearly a mechanical deposit upon the outside of the membrane.

The membranous wall of the vegetable cell is for the most part a permanent structure: forming the "skeleton" of plants, ti usually remains entire until the decay or destruction of the organism in which it exists. It is, as previously stated, in some cases subjected to periodical variations in thickness, according to season. Frequently it becomes absorbed or dissolved,

ultimately at particular points, as at the contiguous end-surfaces of those cells which become fused together to form vessels or ducts; and in the case of the layer closing the outer ends of the canals of the pits or wood-cells, a similar destruction of the primary membrane seems to occur. A phenomenon of this kind is distinctly presented in the large spiral-fibrous cells of *Sphagnum* (fig. 544), where the walls of old cells are found perforated by large round orifices, produced by the separation of circular pieces of the cell-wall, and in the cells of the leaves of *Leucobryum glaucum* (fig. 545). In the cells of the Confervoids producing zoo-

Fig. 544.

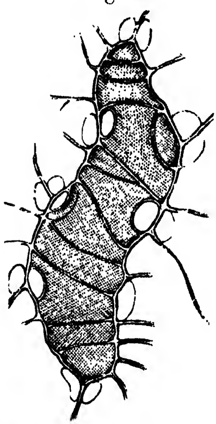


Fig. 545.

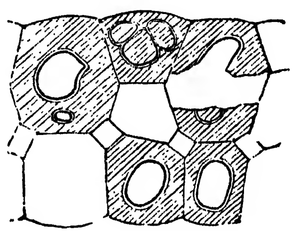


Fig. 544. Cell of the leaf of *Sphagnum cymbifolium*, with annular fibres and orifices in the wall. Magn. 400 diam.

Fig. 545. Porous cells of the leaf of *Leucobryum glaucum*; vertical section. Magn. 400 diam.

spores, the wall breaks open at definite places to allow these to escape, exhibiting small lateral or terminal orifices in *Conferva* (fig. 512, C, *d*) &c., or breaking quite across by a circular slit in *Œdogonium*. In this last genus the cell-wall breaks across in the same way in cell-division, to allow the new cells to expand; and in one of the *Palmelleæ* (*Schizochlamys*) the wall of the parent cell splits off in segments every time a new generation of cells is formed. In the case of the clathrate cells and sieve disks previously mentioned, the bounding membrane ultimately becomes obliterated so as to allow of the passage of the protoplasmic contents of one cell into the cavity of the adjoining cell. If a radial section be made of a latticed cell in the stem of a Vegetable Marrow

and treated with iodine and sulphuric acid, the cellulose becomes stained blue, the protoplasm yellow, and threads of the latter may be seen passing from one cell to the other.

In the formation of the ultimately free cells composing pollen-grains and of the spores of the higher Cryptogamia, the cells are liberated from the parent cells by solution of the wall of the latter. The outer layers of the cell-wall indeed often assume a different appearance from the inner ones; and, as in the case of the pollen-tube, the outer coat dies and splits as the inner coat grows into a tube. A still more curious phenomenon occurs in the process of *conjugation*, where two cells coalesce by complete union of their walls. The last cases appear related in some degree to the origin of the gelatinous coats of the *Palmelleæ* and other Confervoids, which are probably produced by the disintegration of the walls of parent cells, which become softened and swell up as the new generations of cells are formed in their interior.

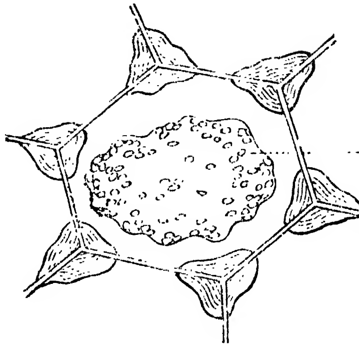
Contents of the Cell.—The solid cellulose structures forming the persistent mass of vegetable tissues may be regarded as a skeleton or framework; for the vital and chemical phenomena exhibited by plants all depend, in the first instance, upon operations which have their seat in the interior of the cells. The careful investigation of the cell-contents is consequently of primary importance in the study of Vegetable Physiology.

The fundamental importance of the matters within the cell is not only demonstrated by what we are enabled to observe taking place in the interior of living cells, but, in certain of the lower plants, the vitalized contents actually emerge from their confinement in the shell of cellulose (as in the case of the so-called *zoospores*), move, perform all the functions of plant-life, and exhibit in the course of their subsequent conversion into closed motionless cells exactly the same power to form new cell-membrane as takes place in ordinary cell-formation.

Cell-sap, &c.—The contents of the cell are partly more or less solid, partly fluid. When substances exist dissolved in the cell-sap, they are frequently out of the reach of microscopic observation, on account of the minute quantities in which they exist, or from the want of suitable reagents to ascertain their presence; among these are the vegetable alkaloids and similar products. The sugar, dextrine, mineral salts, &c. dissolved in the watery cell-sap do not readily admit of examination in this way. The fluid colouring-matters, essential or fixed oils, resins, &c., on the contrary, are readily observed, on account of their distinct physical and chemical characters. This is still more the case with mineral or organic salts which are sufficiently abundant to crystallize in the cell.

But by far the most important of the contents of cells are certain organized structures which are regularly met with in the cell-contents, either universally or, with certain definite exceptions, at particular epochs of the life of cells. These are the *protoplasm*, the *nucleus*, and *chlorophyll-corpuscles*, which are albuminous or proteinaceous in their character, while others are destitute of nitrogen, such as the *starch-granules*.

Fig. 546.



Transverse section of cell of *Jungermannia Taylori*: *a*, the primordial utricle contracted from the action of alcohol. Magn. 500 diam.

Protoplasm. — In all young growing cells we meet with a tough mucilaginous semifluid substance, colourless or with a yellow tinge, and frequently of more or less granular character, which increases with the age of the cell. This substance is called the *protoplasm*.

The sperm or elementary units (male) and the corresponding initial germs, or female organs, are fragments of naked protoplasm. The Myxomycetous Fungi are very remarkable. They consist of masses of protoplasm, called *plasmodia*, uncovered by cell-membrane, and which move by creeping over the substance on which they grow, show currents in their interior, and ultimately form reproductive bodies, covered with a cell-wall formed from their own substance (see p. 470). Latterly Mr. Francis Darwin has shown that protoplasmic filaments may be ejected and retracted from the cells of the leaf of the common Teazel.

Ecto- and Endoplasm.—The protoplasm generally presents a division into two layers—the outer a hyaline film in contact with the cell-wall, and called the *ectoplasm*, the other of a granular character, termed the *endoplasm*. The *ectoplasm* or *primordial utricle* is the outer film of the protoplasm, from which it differs in its greater density and different molecular structure. It may be seen by soaking the tissue in acetic acid, is coloured yellow by iodine, and is applied intimately to the inner surface of the cell-membrane of young cells, persisting in the cells of tissues which are concerned in the reproduction of cells or the performance of the functions of assimilation, &c., but disappearing at a comparatively early period in cells which acquire fibrous or pitted woody secondary layers.

The *ectoplasm*, lining the entire wall of the cell, forms a kind of *sac*; but it is not a membrane in the same sense as the proper cell-wall, since, although it presents a certain cohesion and resistance to the penetration of water, it is not merely flexible, but *ductile*, and capable of moulding itself into new external forms, the sac, in cell-division, becoming constricted into two or more portions without wrinkling. When the zoospores of the Algæ escape from the parent cell, the primordial utricle forms the external boundary of the structure of the zoospore, which has a definite form in each case. The ectoplasm presents a radial striation, rendered more evident by the action of osmic acid. According to Strasburger it consists of small rods of relatively dense substance, with the intervening spaces filled with cell-sap or watery protoplasm. The *cilia* of zoospores, which are extremely fine vibratile threads, are productions

from the rods. The cellulose coat of the cell is secreted by the ectoplasm. The molecular structure of protoplasm is probably varied in different cases. The investigation of this obscure subject is of immense importance, as the functions of life seem to depend on the activity and behaviour of the molecules of protoplasm. They have been recently called ***plastidules***, and, unlike the molecules of the cell-coat, are not crystalline.

The protoplasm is not always readily discoverable in living cells, on account of its close apposition to the cell-wall, but it may be detected by the application of a weak solution of iodine, which colours it brown, and soon causes it to contract and separate from the cell-membrane (fig. 546). The contraction is disadvantageous in some cases, if it go very far, as the layer becomes applied upon the inner cell-contents. The structure is very well seen by placing portions of the green tissue of leaves, &c. (which retain the primordial utricle after acquiring their full size), of the pulp of fruits, the leaves of Mosses or Liverworts (fig. 546), or the filaments of Confervoids, in alcohol, or treating them with dilute nitric or hydrochloric acid. The primordial utricle then separates from the cell-wall without becoming much discoloured. The chemical properties of protoplasm indicate its affinity to albuminoid substances. It is, moreover, mixed with oily substances and inorganic or incombustible materials.

Vacuoles, &c.—In young cells, such as those in the cambium-layer of stems, in the growing parts of leaves, &c., the protoplasm nearly fills up the cavity, or at all events occupies all the space not filled by the *nucleus*. By degrees, as the cell expands, spaces called *vacuoles* make their appearance in the protoplasm, filled with watery cell-sap (fig. 547); they may be regarded as drops of watery fluid surrounded by protoplasm, which latter is thus transformed into a kind of froth, which is often finally displaced so entirely by the cell-sap that it forms merely a layer applied against the primordial utricle. In many zoospores these vacuoles are seen to contract and expand, probably from the varying contractility or degree of turgescence of the surrounding protoplasm. These movements are identical with similar phenomena witnessed in Protozoa, and are the first indications of a respiratory or circulatory system.

Movements in the protoplasm, rendered evident by the movement of the granules floating in it, occur in many plants, probably in all, and are attributed by some to contractility of the protoplasm, by others to alternate turgescence and emptying of certain portions of the protoplasm. They are strictly analogous to the movements seen in *Amœba* and other similar low animal organisms. The protoplasm is said to be ***chambered*** when the cell-sap is traversed by several anastomosing plates of protoplasm.

Nucleus.—In the protoplasm of most young cells, and persistent through life in the parenchymatous structure of some plants, as of the Orchidaceæ, occurs the globular or lenticular body called the *nucleus* of the cell, or *cytoblast* (figs. 547, *n*, & 548), discovered by Bauer, and first investigated by Robert Brown. This appears to be a mass of substance identical with protoplasm, and it mostly

presents the appearance of a central cavity or vacuole containing one or more small granules called *nucleoli*.

Fig. 547.

Fig. 548.

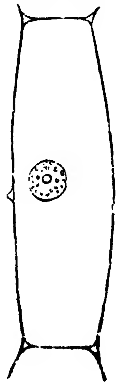


Fig 547. Upper end of a young hair of the stamen of *Tradescantia*, showing the cells in various stages of development: *n*, *n*, nuclei. Magn. 400 diam.
Fig. 548. Cell with a nucleus, from the stem of *Orchis mascula*. Magn. 400 diam.

The nucleus is not usually found in Fungi or Lichens; and many Algæ are likewise unprovided with it.

Movements of the Nucleus, &c.—The nucleus probably originally occupies the centre of all nascent cells where it exists, the interspace between it and the primordial utricle being filled up by protoplasm. When the vacuolar displacement of the latter by watery cell-sap takes place, the nucleus, if persistent, is usually carried to one side of the cell, and comes into contact with the inner boundary of the primordial utricle. Sometimes, however, it remains suspended in the centre of the cell by cords of tough protoplasm, stretched from a layer of protoplasm coating the nucleus to that which lies upon the primordial utricle. The cords of protoplasm radiating from the nucleus are the persistent boundaries of the vacuolar spaces of the "honeycombed" protoplasm. The nucleus itself, according to Hanstein, is dragged out of shape, as it were,

by the contraction of the protoplasmic threads attached to it, and, moreover, itself undergoes, in some cases, changes of form analogous to those manifested by *Amœbæ*. (See under *Myxomycetes*, p. 471.)

The gradual vacuolation of the protoplasm and the transfer of the nucleus to the side of the cell may be well seen in the hairs of the stamens of *Tradescantia* (fig. 547). In *Spirogyra* and *Zygnema* the nucleus remains always suspended in the middle of the cell by the protoplasmic cords. The ultimately parietal nucleus of the hairs of *Tradescantia* exhibits radiating cords, the protoplasm here being in process of absorption. In *Vallisneria* and in *Œdogonium* and other Confervoids, the nucleus becomes imbedded in the continuous parietal layer of protoplasm which lies upon the primordial utricle. The nucleus has the property of breaking up and, as it were, disappearing for a time, to reappear in the form of two or more new nuclei of larger size than the original nucleus. This process occurs in the formation of the pollen in the embryo-sac of Phanerogamous plants, &c. The nucleus is sometimes, according to Cohn, invested with a layer of starch, and is coloured by carmine solution, which leaves the amylaceous envelope unstained.

Chlorophyll.—In all parts of plants which have a green colour we find the cell containing in its cavity structures quite distinct from the cell-wall and from the primordial utricle, in which the green colouring-matter resides. The ordinary form of these is that of globular or spheroidal corpuscles, which appear in greater number and of darker green colour in proportion to the intensity of solar light to which the tissue may be exposed. In a few cases the green colouring-matter is found in the form of annular or spiral bands (*Draparnaldia*, *Spirogyra*, fig. 549), or of reticulated cords (*Cladophora*), of mucilaginous consistence, adhering to the inside of the primordial utricle. In some Confervæ the green colouring-matter appears diffused through a portion of the protoplasm in the form of very minute granules. In many unicellular Algæ, in the Algoid gonidia of Lichens, &c., the green colouring-matter is uniformly distributed throughout the cell, and is not separable from the rest of the protoplasm.

Fig. 549.

Cells of a filament of *Spirogyra*, with spiral green bands. Magn. 200 diam.

The *Chlorophyll-corpuscles* are of soft consistence; and their colour is extracted by ether, alcohol, and various acids. They consist of protoplasmic colourless substance mixed with colouring-matter. The former may exist by itself unmixed; but the colouring-matter is never found separate in nature. They appear

usually solid and homogeneous when young: subsequently they often contain starch-granules in the interior, and not unfrequently they become vacuolated like protoplasm when exposed to the direct action of water.

Frémy states that the green colour of chlorophyll is due to an admixture of two substances, one yellow and the other blue, called respectively *phylloxanthine* and *phyllocyanine*; but others think that the blue substance is a modification of the yellow, brought about by the agency of the acids. Our chemical knowledge of chlorophyll, however, is at present incomplete. Sorby states that chlorophyll exists in a blue and in a yellow state. *Blue chlorophyll* when dissolved in alcohol, is of a splendid blue-green colour, the whole of the green part of the spectrum and part of the blue being readily transmitted. *Yellow chlorophyll* absorbs the whole of the blue and the blue end of the green, so that the colour is a bright yellow-green. *Chlorofucine* is of a clear yellow-green colour, fluorescent like the two preceding. These three varieties of chlorophyll are insoluble in water, soluble in absolute alcohol, but not always in carbon-bisulphide. Other colouring-matters, with different optical properties and soluble in carbon bisulphide, are described by Sorby.

The chlorophyll-corpuscles are probably formed from the protoplasm of the cell breaking up into distinct globular corpuscles, or distributing itself according to patterns, as above indicated, upon the cell-wall. When newly formed, in young cells, they are almost colourless, and appear in the vicinity of the nucleus and in the layers or streaks of protoplasm; and we not unfrequently meet with protoplasmic corpuscles which differ from chlorophyll-corpuscles only in the absence of the green colour.

Development of Chlorophyll.—The development of chlorophyll takes place thus:—In the young cell the protoplasm is colourless and disposed in a thick layer around the inner wall of the cell; in this appears first a yellow colouring-matter; and then the inner portion of this protoplasm gradually splits up into polygonal portions, each of which becomes a grain of chlorophyll. In other cases the chlorophyll is formed in a layer of protoplasm surrounding the nucleus. *Vacuoles* are formed in it, and break up the substance of the protoplasm into granules. In this latter case more uncoloured protoplasm is left after the formation of the chlorophyll than in the preceding case.

Decay of Chlorophyll.—The destruction or decay of chlorophyll shows itself first in the change of colour from green to yellow or orange, or, in the case of the spores of Algæ, to red. This red colour is supposed to be due to oxidation, assumed at the time when the spores come to rest; when active vegetation again commences, the green colour is restored. In the case of leaves at the fall, the grains of chlorophyll diminish, then disappear and give place to highly refracting granules of an orange colour, which are the remnants of the disorganized chlorophyll, and to which the colour of leaves in autumn is due (see p. 540). While these processes are going on,

the starch and the protoplasm are dissolved and stored away in the permanent tissues. In plants kept in the dark Gris noticed that the chlorophyll-grains slowly and gradually become smaller, lose their starch and their colour, till at length nothing but a number of minute amorphous granules remains. Some plants, such as Selaginella, some Ferns, &c., resist the deprivation of light much more than others; but in the case of quickly growing plants, two or three days' obscurity suffice to disorganize the chlorophyll.

Action of Reagents on Nitrogenous Contents.—The protoplasm, the nucleus, and the chlorophyll-granules are all substances containing nitrogen and closely allied to albumen; they are more or less coagulable by heat, alcohol, and acids, and soluble in caustic potash. The principal tests are the following, though it must be remembered that their action is masked by the colouring-matters of the cell, and that they are not in all cases manifested in living, but only in dead cells:—Iodine gives a brown or yellowish tinge to these structures; ammoniacal solution of carmine tinges them pink. When treated with nitric acid, and subsequently with ammonia, a yellow tint is formed, indicating the presence of xantho-protein; when soaked in a solution of copper sulphate and afterwards treated with potash, a violet colour is produced in the protoplasm and chlorophyll; but this has not been observed in the case of the nucleus. It must be remembered that the solubility of protoplasm in acids and alkalies depends not only on the strength of the solvent, but also on the condition of the substance at the time of the experiment.

Aleurone exists in many seeds in the form of roundish colourless granules pitted on the surface, or even presenting facets like those of crystals. The granules occur between the starch-grains, or, in the case of oily seeds, in large roundish or angular masses. They are, for the most part, about equal in size; but here and there one occurs much larger than the rest, and which is remarkable for the rapidity with which it dissolves in water; hence it escapes observation under the microscope when the tissues are examined, as they usually are, in water. Aleurone or *protein-grains*, as they are sometimes called, are insoluble in ether, alcohol, and oil; hence, in order to see the aleurone, the following process is adopted:—Thin slices of almonds or other seeds are soaked in olive-oil, the oil is subsequently filtered and allowed to stand. Some hours subsequently a white powder is precipitated; this is removed from the oil by filtration, and washed in ether or alcohol, so as to remove the oil; it is then allowed to dry, and the resulting powder is pure aleurone. Aleurone-grains often contain, imbedded within their substance, crystals of calcium oxalate, or globose masses of magnesium phosphate. Aleurone is coloured brown by iodine, and the inner portions of the grain assume a brick-red colour after soaking for some minutes in a solution of mercuric nitrate; hence it is considered to be of albuminoid nature, and to be of service in providing nutriment for the developing embryo.

The nature, mode of formation, and chemical history of this substance all stand in need of further investigation.

Crystalloids.—Masses of proteinaceous substance of a crystalline form, but differing chemically from true crystals, occur imbedded in the protoplasm of many plants, especially of such as are in a dormant condition, as beneath the rind of the tuber of the Potato. Their function seems to be to act as a reserve of nourishment to be used when growth becomes active. Similar crystalloids have been seen in many Red Seaweeds.

Starch.—Starch-granules appear to occur throughout every class of plants except the Fungi, and are perhaps most frequently of globular form when young; but when they acquire any considerable size their form usually diverges from this, and presents very remarkable varieties, often attributable to the conditions in which they grow. Full-grown starch-granules are not homogeneous, but marked with striæ indicating the concentric laminæ of which they are composed. These laminæ are alternately of denser and softer consistence, and surround a commonly more or less excentric point, usually of very small size (fig. 550), which often appears solid when the starch-granule is fresh, but which forms a minute cavity, frequently running out into a few radiating cracks, when the starch-granules are dry.

The granules occur either singly or collected in masses of definite shape, forming compound granules (fig. 551); very often they exist

Fig. 550.

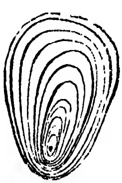


Fig. 551.

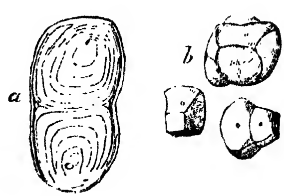


Fig. 550. Starch-granules of Potato. Magn. 400 diam.
Fig. 551. Compound starch-granules: *a*, a double granule from the Potato; *b*, grouped granules and two fragments from the rhizome of *Arum maculatum*. Magn. 400 diam.

in the interior of chlorophyll-corpuscles or bands, or imbedded in the protoplasm lining the cell-wall. In certain tissues they fill the cavity of the full-grown cell, and in some cases so densely that they become moulded into polygonal forms by mutual pressure.

Starch-granules are commonly unaffected by cold water; but when crushed, the inner layers will sometimes absorb it and swell up. Boiling water causes them to swell up into a jelly, losing all trace of their laminated structure—as do also diluted sulphuric acid and solution of potash.

Iodine colours starch-granules violet, indigo-blue, or deep blackish blue, in proportion to the degree of concentration in which it is employed. By means of dilute sulphuric acid, starch may be converted into dextrine and glucose. Modern researches have shown that starch consists of two substances intimately combined, one of which, *granulose*, is more soluble in saliva than the other, *cellulose*; and the action of iodine is also different in the two cases.

Mode of formation.—Great discussion has taken place of late years as to the structure and the mode of development of starch-granules. They are apparently formed of a number of concentric laminæ, which increase in density from within outwards. Their substance is hardly distinguishable from that condition of cellulose where the cell-membrane swells into a gelatinous substance with dilute sulphuric acid, or even sometimes with water, and takes a more or less decided blue colour with iodine alone. With regard to their mode of development, they appear to be formed either by intussusception, as maintained by Nägeli and Sachs, or by the deposition of successive layers of starch-substance, by protoplasm, in the interior of vacuolar cavities formed in the protoplasmic matter of the cell, either while this exists as a colourless mucilaginous matter, or after it has become more highly organized into chlorophyll-corpuscles. Starch-granules, in fact, appear according to this view, to be formed by secretion on the inside of a utricle of protoplasm, exactly in the same way as the cellulose wall of the cell is secreted on the outside of the primordial utricle.

Fig. 552.

Fig. 553.

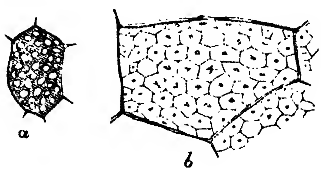


Fig. 552. Part of a cell of the stem of the White Lily: *n*, nucleus, surrounded by protoplasm in which starch-granules (*s*) are being developed. Magn. 400 diam.

Fig. 553. Starch of Maize: *a*, section of a young cell of the seed, with nascent starch-granules imbedded in protoplasm; *b*, section of a full-grown cell with the starch-granules in contact and become angular by mutual pressure. Magn. 200 diam.

This mode of development is well illustrated in the formation of starch-granules in the cords of protoplasm which have ceased to circulate, in

many herbaceous Monocotyledonous stems, as that of the White Lily (fig. 552), &c.,—by the appearance of single or several starch-granules in old chlorophyll-corpuscles, or in the substance of the bands of *Spirogyra* (fig. 549), &c. Still more strikingly is it shown in the development of the starch-granules which ultimately densely fill the outer cells of the endosperm of Maize, where they are at first free from each other, imbedded in a collection of protoplasm filling the cell (fig. 553, *a*), and, as they expand, come into contact and almost displace all the protoplasm, which remains only as a reticulation of slender threads (fig. 553, *b*). A similar reticulation of protoplasm-threads remains on the walls of the cells of the Potato-tuber after its starch-granules are formed.

The origin of the compound granules, in pairs, fours, or very many compacted together into a mass, moulded together by mutual pressure on their contiguous surfaces, is readily explicable, since we often find several isolated nascent granules in one chlorophyll- or protoplasm-corpuscle: as the granules increase in size they come into contact, but remain bound together by the mass of protoplasm in which they lie. Such granules (found in the corms of *Crocus* and *Arum* (fig. 553, *b*), in the Oat, and more or less abundantly in many other Monocotyledonous plants) are mostly simply coherent, so that they may be separated by slight pressure. But it is not uncommon to find twin granules enclosed by external layers common to both (fig. 553, *a*).

Relation to Chlorophyll.—Starch-grains are almost universally present in chlorophyll, from which, indeed, they are formed. This opinion differs from that of Mohl, but is supported by the discoveries of Sachs and Gris, the former of whom shows conclusively that the starch is developed from the chlorophyll under the influence of light, especially in the yellow, red, or orange rays: if light be excluded, no starch is formed, what is already formed disappears, but starch is again formed when the chlorophyll is once more subjected to the influence of light. Without chlorophyll no starch is formed; it may, however, be stored up in cells containing no chlorophyll, but is brought there from the cells in which it is formed.

Decay of Starch-grains.—Starch is a temporary ingredient of the cell-contents; it is accumulated during active vegetation, and is abundantly deposited in the tissues of many organs which remain at rest during certain seasons. In the recommencement of growth it is dissolved, in consequence of the formation of *diastase* (which converts the insoluble starch into soluble *dextrine*), and the assimilated substance is applied to the formation of permanent structure.

Starch-grains are disintegrated or dissolved, when growth is about to take place, in two ways—either locally (when the grains present a worm-eaten appearance) or uniformly over the whole surface.

Inulin.—In certain plants starch-granules are absent in those situations where they are generally abundant, being replaced by a substance of analogous composition, called *inuline*. This has been found especially in the roots of tubers of the Compositæ. It is

not clear whether it occurs dissolved in the cell-sap or in granules mixed with the protoplasm. From solutions it crystallizes in spherical masses of radiating crystals, which may also be seen by dipping the sections of the tissue in alcohol. As it has no special reactions giving distinct colour, like starch, it cannot be detected except by chemical analysis.

Fixed Oils.—The fixed oils, which occur abundantly in many seeds and fruits, are easily distinguished in the cell-contents on account of their forming isolated globules, merely suspended in the watery cell-sap, which strongly refract light, and can be made to run together into large globules by pressure and by the application of ether.

The oil-globules occur mostly in organs prepared for a season of rest, as in the endosperm (Cocoa-nut) or cotyledons (Almond) of seeds, or in the pericarp (Olive) of the higher plants—also sometimes in tubers, as in those of *Cyperus esculentus.* Among the lower plants oil is especially abundant in the resting-spores of the Algæ, taking the place of the starch-granules existing during active vegetation.

Essential Oils.—Essential oils are readily distinguishable when they exist in quantity *suspended in the* cell-sap, or entirely filling the cell; sometimes, however, they exist in such small proportions as to be undistinguishable, as is the case in many scented petals.

The essential oils are developed, like the fluid colouring-matters, in vacuoles of the protoplasm, resolved in time into one large cell-cavity bounded by the layer of the protoplasm lining the primordial utricle. The oily matters, caoutchouc, resins, &c., are usually found in compound cellular organs, *glands, ducts,* &c., to be mentioned presently, under the head of *Tissues.*

Sugar, Gum, etc.—Sugar, dextrine, gum, and similar substances dissolved in the watery cell-sap are not capable of detection by the microscope, since the quantities in which they exist are too small to alter sufficiently the refractive power of the liquids; and we have no colour-test for them.

The *gummy matters* of plants (which swell up in cold water and form a slimy mass) are in many cases parts of the cellulose tissues themselves, as is the case in the seed-coat of Linseed, the Quince, &c., and the gum of Tragacanth, which latter consists of the *collenchymatous* tissue into which the pith and medullary rays of the stem are gradually converted. They result from the abundant formation of secondary layers in that state of the "cellulose" compound which is intermediate between cell-membrane and dextrine, just as the "amyloid" of the secondary layers of the cells of some Lichens is an intermediate condition between cellulose and starch. *Bassorine* and *Arabine* are formed in a similar manner, from the disorganization of the cellulose matters; hence these materials are to be looked on as excrementitious.

Colours of Flowers.—The bright *colours* of the parts of flowers are produced by substances usually dissolved in the watery cell-sap; sometimes, however, solid corpuscles or utricular structures are found swimming in coloured cell-sap.

In young tissues of flowers the colouring-matter may be observed to be formed gradually in the vacuoles of the protoplasm, and, as the cells expand, increasing in quantity until the separate portions coalesce and fill the whole cavity of the cell. This is well seen in the coloured hairs of the stamens of *Tradescantia.*

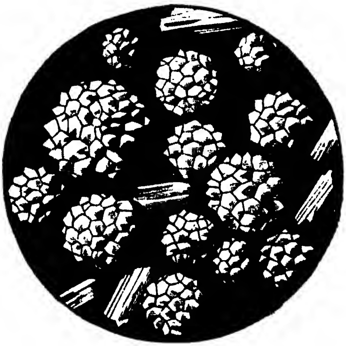
The colouring-matters of flowers admit of being grouped in two series, the cyanic series and the xanthic series, with green as an intermediate colour: thus, starting with greenish blue, the cyanic series passes through blue, blue-violet, violet, violet-red to red; the xanthic series, on the other hand, passes from green to greenish yellow, yellow, orange-yellow, orange, orange-red to red. The cyanic colours are usually in solution; the xanthic colours are usually solid. It very rarely happens that the colours of the two series are met with in the same flower; hence, though Dahlias and Roses of almost all hues are now to be seen, a true blue tint has never been seen in either; and there are numerous illustrations of this fact in gardens. The various tints of colour are produced either by the interposition of colourless cells between those containing coloured juices or by the superposition of cells with different colouring-matter one over the other. Thus an orange tint would arise from the superposition of yellow cells over red, and so forth. White is produced either by a very dilute coloured solution or by the presence of air in comparatively large quantities in the tissues. The velvety appearance of the petals of many flowers is due to the fact that the epidermal cells are raised in the form of small conical elevations like the pile of velvet, and the play of light thereon gives rise to the appearance above mentioned.

Raphides.—The watery fluids traversing the tissues of growing plants, in consequence of the evaporation from the leaves and the continual absorption by the roots, necessarily contain various inorganic salts dissolved in them. Moreover certain organic acids, such as oxalic, malic, tartaric, &c., are always formed in the processes of vegetable digestion. All these substances and their compounds are, for the most part, dissolved in the cell-sap; but in most of the higher plants we find, in certain cells of the parenchymatous tissues, crystals of definite composition, either scattered or collected into groups of definite form. These crystals are called *raphides* (fig. 555). They are common in certain orders of Flowering Plants and Fungi, though others seem destitute of them.

It is not clear whether the raphides are to be regarded as a secretion or as an excretion—that is, as substances useless or noxious to the plant, laid by in an insoluble form. The latter seems more probable, especially as they are usually deposited in tissues of enfeebled vitality. The Polygonaceæ (for example, the Garden Rhubarb) form abundance of oxalic and other organic acids, and they always contain a quantity of bundles of raphides composed chiefly of calcium oxalate; in old stems of Cactaceæ,

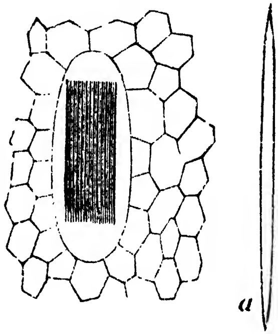
the substance of the parenchyma is rendered quite gritty to the touch by crystals of calcium oxalate and phosphate (fig. 554); the Musaceæ contain crystals of calcium sulphate, &c. The large *spicular cells* of *Araucaria* and of *Welwitschia,* already referred to, are covered with small crystals.

Fig. 554.



Clustered crystals from *Cactus.*

Fig. 555.



Acicular crystals (raphides) in a cell of *Polyanthes tuberosa*, magnified 400 diam.: *a*, a single crystal, more magnified.

Crystals usually occur free in the cavity of the cell; but in some plants, especially in the Urticaceæ, we find them accumulated on a clavate process, formed of cellulose, developed from the side-wall of the cell: these are called *cystolithes.*

These curious structures are well seen in the subepidermal cells of the leaf of *Ficus elastica* and other species—also in *Parietaria*, the Mulberry, &c.

Other important substances, such as the vegetable alkaloids and the great number of organic acids usually associated with them, exist either dissolved in the cell-sap, intermixed with the protoplasm, or diffused in the solid cell-structures as impregnating or incrusting substances. With regard to these, microscopic investigation has not hitherto afforded any information.

Sect. 3. Combinations of Cells.

Tissues consist of collections of cells of uniform character combined together by apposition or by more or less complete union of their outer surfaces. They are produced by the aggregation and juxtaposition of cells of equal age or degree, originally separate and distinct, or more frequently by cells which are formed by repeated subdivisions of preexisting cells. In the one case the tissue is multiple from the first as to its elementary constituents; in the other it is,

at least relatively, simple, its constituents being the descendants of a small number of cells.

The simplest mode of combination of cells is that which is met with in a large number of the Algæ of low organization, where the cells are associated for a time in what are called *colonies*, the members of which are more or less completely independent of each other in physiological respects, but morphologically represent parts of a determinate whole; while ultimately they separate, each to lay the foundation of a new colony.

Examples of this may be seen in the grouped *Desmidieæ*, like *Pediastrum* (fig. 503, B, *a*), the *Diatomeæ*, &c., and in the *Palmelleæ*; to this head is also referable the structure of some of the filamentous Confervoids, Volvocineæ (fig. 503, D), and *Hydrodictyon*. These groups of cells are either held together by simple attachment at certain points of their surfaces, as in the *Desmidieæ*, *Hydrodictyon*, *Diatoma* (fig. 503, B, *c*), &c., or by their being enclosed in a gelatinous common envelope (resulting from the expansion or the decay of parent-cell membranes), as in the *Volvocineæ*, *Palmelleæ*, and *Nostochineæ*.

Intercellular boundaries.—A complete coalescence of the cellular membrane of one cell with that of its neighbour so as to form a homogeneous whole takes place, so that, although the bounding membrane between one cell and another would appear necessarily to be double, each cell having its own proper cell-wall, yet if very young growing tissues be examined where the cell-walls are very thin, the boundary-wall between adjacent cells may be seen to be simple, without any trace of separation. It is only in older thick-walled cells that a line of demarcation becomes obvious, in the form of an intermediate lamella, at one time spoken of as the *intercellular substance*, and supposed to be a distinct substance, but which is now shown to be the result merely of a difference in density or molecular structure of the cell-walls during their thickening.

Where the cells, during growth, separate at various points one from another to form *intercellular spaces*, there the boundary-walls necessarily split to form the spaces in question. So also where cells originally united become disconnected, as in the pulp of fruits, the partition-walls naturally become separated, though originally the boundary-wall is uniform and homogeneous.

Parenchyma.—The tissues are distinguished into kinds according to the form of the cells, the character of the cell-membrane, and the manner in which the cells are connected together.

Where the cells are roundish or elliptical, the tissue is called *parenchyma*; and this is called imperfect or perfect accordingly as the constituent cells have interspaces between them or are closely packed so as to leave no intercellular spaces. Where the cells are much elongated, the tissue is called *prosenchyma*, and the constituent cells are known as fibres. Cartilaginous tissue is known as *collenchyma*; and two other kinds are

characterized by peculiar modes of combination of the cells, viz. felted tissue (*tela contexta*) and vascular tissue.

Imperfect parenchyma (*merenchyma*) is composed of cells with more or less rounded surfaces connected into a lax tissue, necessarily presenting abundant intercellular passages and spaces. The cells are tolerably uniform globular or oval (*a*), or lobed, and connected at few points, leaving wide intercellular passages between them (*b*); in other cases the cells are more or less stellate, and leave large spaces between them (*c*).

The form *a* is common in all young organs of the higher plants, especially in the rind and the pith (fig. 520), in the pulp of fruits, &c.; *b* is very characteristic of the lower stratum of the internal substance of leaves (fig. 522); *c* occurs in the stems and leaf-stalks of aquatic plants, in the pith of Rushes (fig. 524), &c.

Perfect parenchyma is composed of cells bounded and united together by plane surfaces; where the cells are regular polyhedra, of about equal size, the tissue is (*a*) *regular parenchyma*; if the size is unequal and the forms unlike, the tissue becomes (*b*) *irregular parenchyma*. Certain modifications of regular parenchyma have received distinct names, viz.:—(*c*) *prismatic parenchyma*, where the cells are 6-sided prisms with pyramidal ends; (*d*) *muriform parenchyma*, where the cells are square or oblong, with the long diameter horizontal, and packed like bricks in a wall; and (*e*) *tabular parenchyma*, where the cells are flattened from above downwards.

The form *a* is abundant throughout all classes of plants, and is well seen in fully developed pith of Dicotyledons (fig. 526); *b* is even more common in the soft parts of plants (fig. 527); *c* is met with in the herbaceous stems of Monocotyledons, and in the upper part of the diachyma of leaves, also in a woody condition in the testa of various seeds; *d* is characteristic of cortical structures, and may be seen in cork, periderm of Birch, the rind of the rhizome of *Tamus* &c., also in the medullary rays of Dicotyledons; *e* occurs specially in the epidermal cells.

Merenchyma and parenchyma in their various modifications run into one another by countless intermediate conditions.

Sclerenchyma consists of ordinary cellular tissue, the constituent cells of which become ultimately filled with stratified woody thickenings. They occur locally, even as individual cells or in groups (*sclerites*), or even in more or less continuous layers. A familiar illustration occurs in the "grit" of Pears. Their purport is supposed to be to protect and support softer tissues.

Prosenchyma is composed of cells elongated greatly in one direction, and attenuated to a more or less acute point at each end, forming what is called a *fibre*. These fibres are necessarily united for the most part by their lateral surfaces, and their ends are insinuated into the spaces between those lying above and below them.

We distinguish in prosenchyma two modifications—(*a*) *woody fibre*, composed of spindle-shaped cells of moderate length, and (*b*) *liber* or bast cells, composed of very long slender cells which are occasionally slightly branched.

Woody fibre is the main constituent of the trunks of Dicotyledons; its cells are mostly of rectangular section, and the walls become greatly thickened with age. *Liber*, the fibrous substance of the bark of Dicotyledons, a principal constituent in the fibro-vascular bundles of Monocotyledons (fig. 521), and of the fibrous husks of fruits, &c., is composed of very long cells, whose membranes are of a peculiar toughness, even when greatly thickened; their section is commonly roundish (fig. 529) or hexagonal. The peculiar tenacity of the vegetable fibres, Flax, Hemp, &c., arises from the forms and mode of union of the liber-cells of which they consist; the "grain" of wood is likewise determined by the direction of the long axis of the prosenchymatous cells of which it is composed.

Conducting cells are long, cylindrical, thin-walled cells, placed one over the other, and not tapering at the ends, and are supposed to be channels for the passage of the nutrient fluid.

Collenchyma is a substance formed especially at the points of contact of cells. It is of a cartilaginous or horny texture, its cells becoming greatly thickened by secondary layers of a substance softening or swelling up in water, or on the addition of weak sulphuric acid. It never becomes lignified.

The lamination of the cell-walls is often invisible until after maceration; so that the tissue looks like a mass of homogeneous substance, excavated into cavities, or like a collection of cells with abundant intercellular substance. A solution of chromic acid also serves to show the laminated structure; but if used too strong, it dissolves the intercellular substance. The outer portion is not coloured by Schulze's solution or anilin; but the inner portion next the cell-wall is tinted blue with iodine. This tissue occurs in the rind of many herbaceous plants, as Chenopodiaceæ (figs. 556 & 557), *Cucurbita*, *Nymphæa* (fig. 535), and the pith and medul-

Fig. 556.

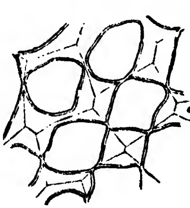


Fig. 557.

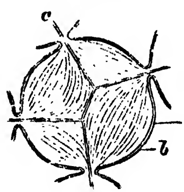


Fig. 556. Transverse section of collenchyma-cells of the stem of Beet: *a*, thickened cell-wall. Magn. 400 diam.

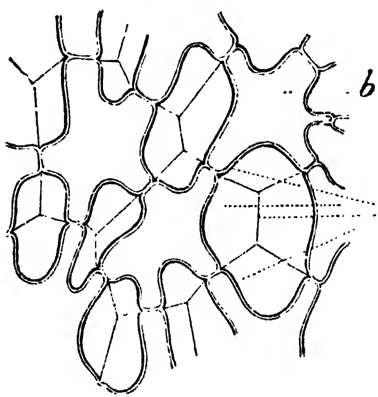
Fig. 557. Section of the junction of four cells (*a*) of fig. 556, treated with hydrochloric acid: *a*, lamina bounding the cavity of the cells; *b*, swollen secondary layers; *c*, primary membrane. Magn. 400 diam.

lary rays of the species of *Astragalus* (forming "tragacanth"); and to the same head may be referred the substance of fleshy endosperms (fig. 558), and also the cartilaginous thallus of the larger Algæ.

Tela contexta is composed of elongated cylindrical cells, sometimes called *hyphæ*, united end to end into filaments, and either simple or branched laterally, interwoven irregularly into a kind of felted mass.

This tissue occurs in the thallus of Lichens, forming the internal or medullary substance, also in the thallus of some Algæ. The mycelium of the Fungi is likewise composed of felted cellular filaments forming a free cottony mass (fig. 1 B, p. 8).

Fig. 558.



Section of the cells of the seeds of *Sophora japonica*: *a*, thickened cell-walls; *b*, cavity of the cells (bounded by a double line). Magn. 400 diam.

Vascular Tissue.—*Vascular tissue* is formed by the absorption of a portion of the contiguous walls between cells, so that they become converted into continuous tubes of more or less considerable length.

When the constituent cells have spiral-fibrous secondary thickenings, they are usually of prosenchymatous form, and they overlap each other so that the lines of union are oblique: sometimes these spiroid tubes are distinguished as *vessels* from those formed of the usually shorter, mostly wider, and more or less flat-ended cells which have pitted walls, and which are called *dotted* or *pitted ducts*.

The dotted ducts are connected with the spiroids through the scalariform vessels, but in their extreme forms are very unlike, and are found in very different situations.

The vessels, like the cells, may be *spiral*, *annular*, *reticulated*, or *scalariform*. They also present special forms hereinafter mentioned. The constituent cells may be long or short; in the latter case the vessels are sometimes called *moniliform*. The spiral-fibrous structure often remains when the primary membrane is absorbed at the surface of junction, so that the constituent cells of a vessel are merely separated by a kind of "grating" of bars.

Spiral vessels (fig. 559) are found in the youngest and most delicate parts of the plants in which they occur. They are the parts of the woody structure first developed in stems; they are extensively developed in the ribs of leaf-stalks and leaves, and almost exclusively constitute those of

the organs of flowers, as may be seen in petals. In stems and leaf-stalks, especially of fast-growing organs, the constituent cells are often very

Fig. 559.

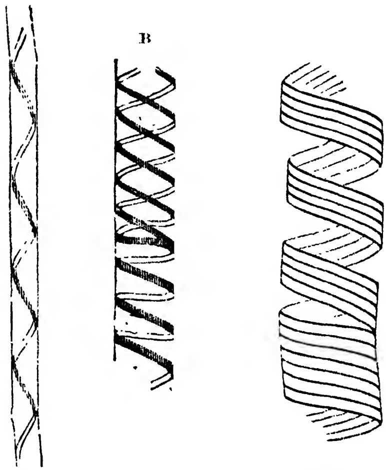
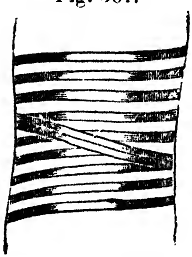


Fig. 559. A, B. C. Spiral vessels from *Sambucus Ebulus*. Magn. 400 diam.

Fig. 562.

Fig. 560.

Fig. 561.



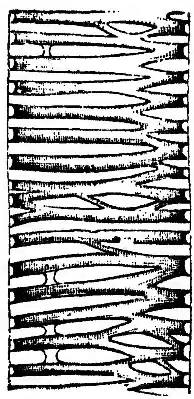


Fig. 560. Fragment of a vessel from the stem of a Gourd. Magn. 400 diam.
Fig. 561. Fragment of a spiral vessel of *Impatiens parviflora* Magn. 400 diam.
Fig. 562. Fragment of the wall of a reticulated vessel of Rhubarb. Magn. 400 diam.

long and the course of the vessels straight; in roots, and in concentrated rhizomes and corms, &c., the constituent cells are mostly short and the course of vessels tortuous. The spiral fibre in the interior of these vessels has been considered to be hollow or tubular; but this is not generally regarded as correct. Ultimately they are empty alike of protoplasm and cell-sap, and serve as air-conductors.

Annular vessels (fig. 560) are found in situations similar to the last, being generally formed a little later in the same bundles. They are commonly of greater diameter than true spirals. This is the commonest form of vessel in the Equisetaceæ.

Reticulated vessels (fig. 562) are abundantly developed with the spiral and annular kinds in succulent stems, roots, petioles, &c. They are very important constituents in the fibro-vascular bundles of Monocotyledons generally. They are mostly of rather large diameter; their cells long in stem-structures, short and irregularly formed in roots and in the inner cortical region of Monocotyledonous stems, where a number of vessels are often anastomosed into a kind of network.

Scalariform vessels (fig. 541) are especially characteristic of the woody structures of the Ferns and Lycopodiaceæ, in which they sometimes occur of very large diameter. Most vessels are cylindrical, and present a more or less circular section; but the scalariform are prismatic, usually with an hexagonal section.

Vessels, when once formed, are usually persistent; but in some water-plants the stem when young is traversed by a single spiral vessel, which disappears as the stem grows older, so that in the adult condition the stem seems wholly cellular with a central lacuna.

The *pitted* or *dotted ducts* (fig. 536) are characteristic of the wood of Dicotyledons, where they occur either scattered in the prosenchyma, or forming the principal constituent of the wood.

The walls of pitted ducts are not always uniform, this depending in some cases upon the nature of the organs with which they are in contact, whether cells or other ducts, since the pits always correspond on the walls of adjacent organs, and they are ordinarily less numerous and less regular on the walls of prosenchymatous cells than on those of ducts.

The pits and their borders (p. 487) are very generally somewhat elongated obliquely; and the canal of the pit is often enlarged into a transverse slit in the inner part, which in some cases becomes confluent with that of its neighbours. In some plants we find ducts with the wall marked both with pits and a spiral fibre, like the walls of the wood-cells of *Taxus* (fig. 542).

Pitted ducts with uniform walls make up the chief mass of the wood of *Clematis*. In the wood of Elder, Beech, Hazel, Alder, &c. we find ducts with pits numerous on the walls adjoining other ducts, but distant or absent on the walls adjoining wood-cells. In *Bombax* the wood-cells are for the most part replaced by parenchyma-cells, and the walls of ducts adjoining these have the pits destitute of the border &c.

Pitted ducts form the large tubes, visible to the naked eye, seen in cross sections of most woods, especially Oak, Mahogany, &c. They are absent from the wood of the Coniferæ, which is wholly composed of simple wood-cells (fig. 537).

Vasa propria are elongated cells with thin walls, and either oblique

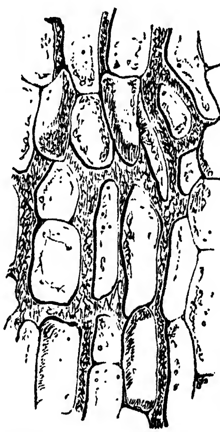
or flat ends, where they adhere together; they vary in diameter, like the spiroids, and sometimes present on their walls large pits or spaces, covered with a kind of fine network of fibres, as in the clathrate cells described in a former section.

Cells of this character (which differ from the *conducting-cells* before alluded to, in that the latter are destitute of markings or pits) always occur in the middle of the fibro-vascular bundles of Monocotyledons; and they are intermixed, mostly in alternate layers, with the liber in the fibrous layer of the bark of Dicotyledons. They are strikingly distinguished from *spiroids* by containing thick and opake sap, while the latter usually contain only air when fully developed.

Caspary includes under the head of *conducting-cells* not only those cylindrical tubes before alluded to, but also elongated cells having the form and appearance of vessels, but which do not form continuous tubes, being separated one from the other by partitions formed by the adjacent ends of the cells.

Laticiferous vessels, or milk-vessels, containing the *latex* or milky juice of such plants as Poppies, Euphorbias, Cichoraceæ, &c., are formed from series of cells, the partitions between which become very early and speedily obliterated. The constituent cells may be placed one over the other to form ultimately a straight tube, or, more generally, the lateral partition-walls between the cells become obliterated, and the result is a branching tube, or series of tubes, which, according to Trécul, anastomose with other kinds of vessels, and allow the contents of the one to pass into the cavity of the other. They occur most abundantly in the pith and inner layers of the bark, in roots, leaf-stalks, &c., often forming a complete network. Dippel says the laticiferous vessels replace the clathrate or latticed vessels of other plants. Their presence is most easily demonstrated by boiling a fragment of tissue in weak solution of potash.

Fig. 563.



Laticiferous canals from the root of Dandelion. Magn. 100 diam.

Vesicular vessels (Hanstein) resemble simple unbranched laticiferous vessels, containing a milky juice. They are formed of rows of cells disposed lengthwise, and their partition-walls are thickened and perforated as in the *sieve cells* (see p. 487). This form of vessel occurs in the bulbs of Onions and other Monocotyledons.

In Commelynaceæ and in Pandanaceæ long rows of cells are met with filled with raphides, and ultimately forming continuous tubes, which are stated by Hanstein to be homologous with latex-tubes.

Tyloses.—In some instances, as in the Vine, vesicular formations may be seen in the interior of the large vessels. According to Von Mohl, they are produced by a protrusion of the adjacent cell, which penetrates

the pore, and either tears through or causes the absorption of the primary membrane of the vessel.

The Systems are combinations of tissues, of like or different form and character, into elementary structures formed on definite plans, and destined for particular purposes in the economy of the plant.

In the simpler plants there generally exists no distinction of systems; but even in the higher Algæ and Lichens there is a difference in the cortical and medullary portions of the thallus. In plants possessing stems and leaves, the fibro-vascular or wood-system makes its appearance; and we may distinguish in the Phanerogamia three primary systems, viz. the *Cellular*, the *Fibro-vascular*, and *Cortical Systems*. These are all formed of proper constituent cells or tissues.

Besides these, we have systems which are formed for the most part by the interspaces between the cells of the above tissues, viz. the *Aërial System*, consisting of intercellular passages, spaces, or even large cavities: and the *Secretory System*, including the milk-vessels, reservoirs for secretion, glands, &c.

The Cellular System.—This name is applied to the cellular tissues forming the great mass of the living structure of plants. In the Thallophytes it forms the whole organization, the superficial layer of the larger kinds of thallus not being a true cortical layer like that of the higher plants. In the Mosses and Hepaticæ little is added to the cellular system, the *fibro-vascular* system appearing in a very simple form in the stems, and the *cortical* in the shape of an epidermis to the seta. In the higher Cryptogamia and the Phanerogamia the cellular system is less predominant, except in the temporary organs. In the stems and roots it forms the pith and medullary rays of Dicotyledons, and the diffused medullary system of Monocotyledons, together with the cambial structures in all growing regions; and it forms the mass of the leaves and the parts of the flower. It is in this system that the vital processes of vegetation are chiefly carried on. If the constituent cells do not grow or divide, they constitute a *permanent* tissue; but if the cells divide, they form meristem, or generating tissue.

Meristem.—That part of the parenchyma, or cellular tissue, whose constituent cells multiply, or are capable of multiplying, by division, as subsequently explained, is called *meristem*. According to Hanstein's researches on the development of the tissues in the embryo plant, the meristem or growing cellular tissue, in the course of its development, gradually undergoes changes which result in the formation of distinct layers of cells—differing in size, form, and mode

of division, and which may be grouped under the three heads of *dermatogen*, *periblem*, and *plerome*. From the dermatogen-cells the root-cap, the epidermal tissues and their appendages, hairs, &c., develop themselves. The cells constituting the periblem are the precursors of the cortical tissues. The cells of the plerome form the *pericambium*, *procambium*, *cambium*, and ultimately the fibro-vascular bundles and pith. The pericambium is only found in roots, and is merely the outer layer of the plerome (McNab). The *procambial cells* are those which are destined to develop into the fibro-vascular bundles. The cambium is that portion of the original plerome which is not converted into fibres or vessels, but the cells of which retain their more or less spherical form and their power of subdivision. The cambial cells occupy the centre of the fibro-vascular bundles of Dicotyledons, between the outer phloëm portions and the inner xylem or vascular portions. At the extreme apex these layers are not yet differentiated, but form a mass of cells of equal size and degree, sometimes called the initial cells. In many Cryptogams, however, the ends of the stem and of its subdivisions are constituted by a single apical cell.

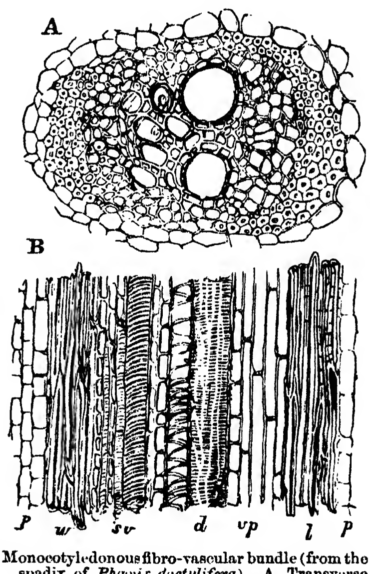
The Fibro-vascular System.—This system forms all the woody structures of plants, which in all cases are composed of a quantity of conjoined portions of cellular and vascular tissue arranged in a peculiar manner, and derived originally from a definite portion of the plerome called the *procambium*. The cells of this latter are either all converted into *permanent tissue* (vessels, liber-cells, &c.), or some of them remain in a merismatic condition, if capable of division, and these form the *cambium*. The kind of cellular tissue associated with the vessels is mostly *prosenchyma* or *fibrous* tissue; the constituent elements wood of are called *fibro-vascular bundles*. In Dicotyledons the fibro-vascular bundle usually consists of wood-cells and vessels (xylem) internally, liber-cells (phloëm) externally, separated by *cambium*. The bundles are plunged in parenchyma. If the bundles are devoid of meristem or cambium they are *closed*; if, on the other hand, they contain cambium, the bundles are called *open*. All woody substance appears originally in the condition of isolated fibro-vascular bundles, which, when they remain separate, form what are commonly called "fibres," and when they combine together into a solid mass, form "wood." The bundles remain as "fibres" in the stems of Monocotyledons; they are in the same state in the earliest conditions of the stems of Dicotyledons; and such "fibres" form the ribs of leaves and other organs.

That portion of the parenchyma which remains after the conversion of the meristem into fibro-vascular tissue is called the *fundamental tissue*.

The fibro-vascular bundles differ in their mode of growth in *different Classes of Plants, which*, in consequence of this, exhibit considerable difference in the structure of their mature stems. The simplest form is absolutely without vessels, as in Mosses and some simple aquatic Phanerogamia (*Potamogeton*), where the fibro-vascular tissue is composed simply of cords of prosenchyma traversing the cellular tissue.

Complete bundles, however, possess several elements arranged in definite order; these belong to the wood-region, the cambium-region, and the liber-region. *The wood-region, which lies next the centre of the stem, is composed of short-celled prosenchyma inter*mingled with spiral and other vessels (and in Dicotyledons pitted ducts); the *cambium*-region is composed of prosenchyma in a nascent condition. The increase of such stems depends on the development of new cells in this region. The *liber*-region is composed of very long prosenchymatous tissue (usually in the condition of isolated bundles of thin laminæ connected by cellular tissue in the Dicotyledons). In the Monocotyledons the region is converted into *vasa propria* (fig. 564).

Fig. 564.



Monocotyledonous fibro-vascular bundle (from the spadix of *Phœnix dactylifera*). A. Transverse section. B. Vertical section: *p*, parenchyma in which the bundles lie; *w*, wood-cells; *s v*, spiral vessels; *d*, reticulated ducts (from *w* to *d* are included in the woody portion of the bundle or xylem); *v p*, *vasa propria*; *l*, liber-cells (from *v p* to *l* are included in the phloëm or liber part of the bundle). Magn. 100 diam.

In the Higher Cryptogamia there is no dermatogen, but only periblem surrounding the plerome; the bundles are *closed*, and do not alter in their condition when once formed, and they anastomose with those that succeed them in successive internodes of the stem, so that the fibro-vascular structure appears *continuous*.

In the Monocotyledons there is but little periblem; the bundles are also *closed*, are formed by degrees, a cambium-region being formed from the plerome and occupying the central part at first; but after a time this is wholly resolved into wood, liber, and *vasa propria*. These bundles remain isolated

in the stem, never alter in condition after the first season of growth, and turn outwards to terminate at the surface of the stem above and below, anastomosing with their successors.

In the Dicotyledons the bundles in a young shoot somewhat resemble those of Monocotyledons, but they stand in a regular ring round the pith. On the inside they present spiral and annular vessels; next, a mass of prosenchyma with dotted ducts, which passes gradually into the cambium-layer; the latter is bounded externally by liber, among the bundles of which are *vasa propria*. These bundles are indefinite in their growth, producing new layers of permanent tissue, liber-cells on one side of the cambium and wood-cells on the other. Hence the division of the bundle into *phloëm* or bast tissues, and *xylem* or wood, separated by the cambium when present. The phloëm consists of thin-walled, often latticed cells, sieve tubes, and of large thick-walled liber-cells. The xylem consists of thick-walled cells and pitted vessels, surrounded by woody parenchymatous cells. Sometimes the cells do not become woody. Great variations occur in the degree in which the several elements are present, even at different parts of the same bundle. The lower extremities elongate indefinitely in the root; the upper extremities anastomose and become continuous with their successors; and above all, the cambium-region is an indefinite focus of development, forming a new layer of woody substance inside, and a new layer of liber outside during every season of growth.

Protecting Sheath.—This term is applied by Caspary to a single layer of cells without intercellular spaces surrounding each fibrovascular bundle, or surrounding the entire ring of bundles. By Van Tieghem this layer is called the *endoderm*. Its cells are usually more or less lignified.

The Cortical System. Epidermis.—In young stems and in herbaceous organs generally this system is termed the *epidermal system*; as stems grow older, this gives place to the *bark*. The cortical system may therefore be defined as comprising all the tissues outside the cambium ring when present.

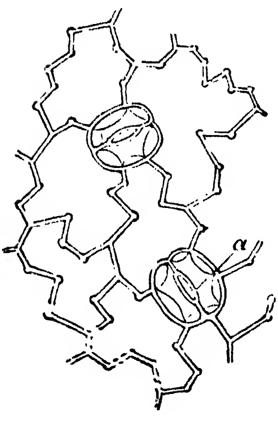
The simplest form in which the cortical system exists is that of a simple layer of flat cells firmly united by their sides, forming a continuous coat over the surface of a plant, called the *epidermis*. The constituent cells of the epidermis do not divide tangentially, but always parallel to the surface. These cells, moreover, are entirely devoid of chlorophyll or granular matter, and are derived from the dermatogen cells. The epidermis is usually caducous, being succeeded by the formation of corky periderm cells. Where the stem remains green the periderm is not formed, but the epi-

dermis persists. Such an epidermis clothes all the organs of plants above the Class of Mosses; and it presents this simple general character on all young structures, with one special distinction only, that on submerged organs and on roots it is absolutely continuous and impervious; while on parts exposed to the air it presents more or less numerous orifices guarded by a peculiar cellular structure called a *stoma* (fig. 565, *a*).

Stomata.—The *stomata* are orifices between the meeting angles of the epidermal cells (fig. 566, B), in which orifices lie, rather to the underside, a pair of cells of semilunar form (fig. 566, A, C), separate on their adjacent sides, so that in expansion and contraction they close and open a slit-like passage beneath the superficial orifice. This slit (fig. 566, A, *s*) leads to an open intercellular space within the substance of the leaf.

Fig. 566.

Fig. 565.



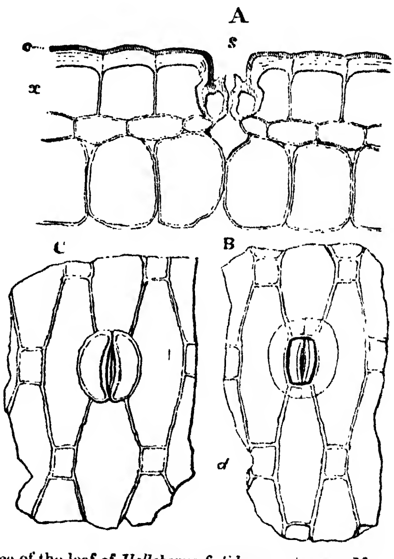


Fig. 565. Epidermis of the lower surface of the leaf of *Helleborus fœtidus*: *a*, stoma. Magn. 200 diam.

Fig. 566. Stomata of the leaf of *Narcissus Pseudo-Narcissus*. A. Vertical section of the epidermal and subjacent cells, passing through a stoma, *s*: *c*, cuticular pellicle extending down into the stomatal cavity. B & C. Horizontal section of the epidermis, passing through the plane of *x* in A: B, seen from above; C, seen from below; *d*, smaller epidermal cells corresponding in position to the stomata, but remaining in their original condition. Magn. 200 diam.

In *Nerium* the stomata are on the walls of pits or depressions on the under face of the leaf. Sometimes the stoma is formed of four cells, and

then either in two pairs, as in *Ficus elastica*, or the four cells form the quadrants of a circle, as in various Proteaceæ.

Stomata are most abundant usually on the lower surface of leaves, often wanting on the upper surface—except on the floating leaves of aquatic plants, where they exist on the upper surface, and are absent where the leaf touches the water. They are occasionally found in the interior of organs, as on the *replum* of Crucifers. They vary in frequency, partly bearing proportion to the size of the cells of the epidermis, partly irrelative to this. Sometimes 100 will be found in a square line, sometimes as many as 1000 to 3000. On the leaf of *Brassica Rapa* a square line bears 1800 on the upper face, 3500 on the lower; *Victoria regia* 1800 on a square line above, and none below. A few other examples may be cited.

	On the upper face.	On the lower face.
Cherry-Laurel	None.	625 to a square line.
Laurustinus	do.	625 „ „
Daphne Mezereum	do.	30 „ „
Carnation	250	250 „ „
Garden Flag	80	80 „ „
Garden Rhubarb	7	30 „ „
Lilac	None.	1000 „ „

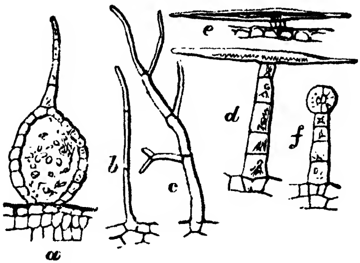
From the researches of Duchartre, Morren, and others, the following conclusions may be drawn, subject, however, to many exceptions. Stomata are more abundant in woody than in herbaceous plants, in leathery leaves rather than in those of thinner texture. Succulent leaves contain the smallest numbers of stomata. Where leaves are alike in texture and colour on both surfaces, the number of stomata is about equal on both sides; when one side is glossy and the other dull, the stomata are most abundant on the latter, &c.

Form of Epidermal Cells.—The cells of the epidermis exhibit a great variety of forms in the leaves and petals of Phanerogamia. It is very common for the side-walls, by which they adjoin, to be sinuous or zigzagged, often presenting very elegant patterns (fig. 565), especially on petals. The external wall of the cells is usually more or less convex; and in petals this condition is carried further, through numerous gradations, until we find a papillose condition, arising from each epidermal cell being produced above into a little obtuse cone.

Hairs; Trichomes.—Hairs and scales of all kinds, "scurf," such as we see in the Bromeliaceæ &c., depend on the development of the epidermal cells. Simple hairs are merely single epidermal cells produced into a tubular filament; cell-multiplication usually occurs in such hairs, so that they present a number of joints (fig. 567, *b*); and not unfrequently they are more or less branched (fig. 567, *c*, *d*). Glandular hairs differ merely in certain of their cells secreting oils or resins in their cavities (fig. 567, *f*.) Scales are produced by epidermal cells growing out into flat cellular plates instead of projecting filaments. Thorns, such as those of the Rose, the prickles of leaves, like those of the Holly, &c., are epi-

dermal products in which the cells become thickened by woody secondary deposits.

Fig. 567.



Epidermal appendages: *a*, gland of *Fraxinella*, in vertical section; *b*, simple jointed hair of *Pelargonium*; *c*, hair of *Sisymbrium Sophia*; *d*, hair of garden Chrysanthemum; *e*, hair of a *Grevillea*; *f*, hair of the bulbil of *Achimenes*, with a glandular terminal cell. All magn. 50 diam.

Thickening layers of Epiderm-cells.—The most remarkable diversities of condition of texture of herbaceous organs depend on the consistence which the epidermal layer acquires. The leathery texture of evergreens, the woody character of the leaves of Conifers, &c. depend chiefly on thickening of the wall of the epidermal cells.

In all epidermis exposed to the air, the outer walls of the cells

Fig. 568.

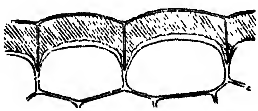


Fig. 569.

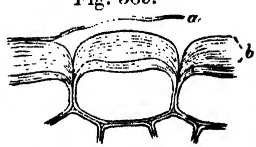


Fig. 568. Vertical section of epidermal cells of the leaf of *Hoya carnosa*: *a*, the portion of the secondary layer coloured yellow by iodine. Magn. 440 diam.

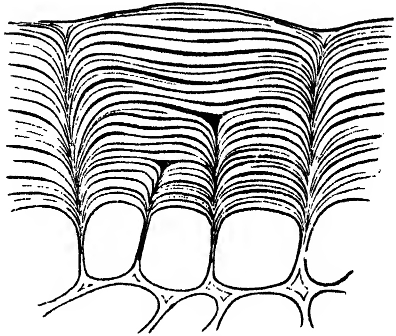
Fig. 569. Section as in fig. 568, treated with caustic potash: *a*, detached cuticular pellicle; *b*, the layers of thickening of the outer walls of the cells. Magn. 440 diam.

become early strengthened by secondary thickening; these are very thin and slight in soft herbaceous leaves, especially when such plants are reared in a warm, moist atmosphere. In leathery or hard leaves, also in the thick tough leaves of succulent plants, such as the Aloes, *Hoya* (figs. 568 & 569), &c., the secondary layers acquire great thickness; and in the epidermis of the branches of *Viscum* (fig. 570) the cells become absolutely filled up, and the cells of the subjacent layer of tissue also suffer the same change.

In the course of this thickening, the superficial laminæ, exposed to the

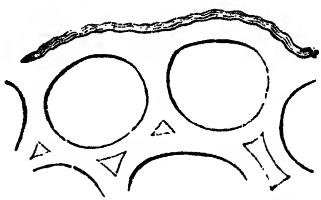
air, become more or less chemically changed, and at the same time fused, as it were, into a continuous layer all over the surface of the organ; and by maceration, or applying nitric acid, we may separate this outer stratum as a continuous sheet or pellicle. This layer, which strongly resists decomposition, is called the *cuticle* (figs. 569 & 571, *a*), and is constituted by the altered outer walls of the cells. It is usually blended with waxy material, which sometimes exudes in the form of "bloom," as on the surface of some fruits and leaves. Unlike cellulose, cuticular structures are dissolved in caustic potash, but not by sulphuric acid. Iodine and sulphuric acid stain them yellow. These characteristics are similar to those possessed by cork. Anilin and sulphuric acid, according to Wiesner, do not stain them as they do vasculose.

Fig. 570.



Vertical section of epidermal cells of old stem of *Viscum album*. Magn. 400 diam.

Fig. 571.



Vertical section of epidermal cells of *Helleborus fœtidus*: *a*, cuticle. Magn. 440 diam.

In *Cycas* the inner laminæ of the secondary deposits exhibit pits like those found on the walls of wood-cells; but this is a very rare phenomenon.

The aërial roots of Orchidaceæ exhibit a curious structure, the growing extremities being clothed by a whitish cellular tissue composed of several layers of cells with a delicate spiral fibrous deposit on their walls. This layer forms a kind of coat over the real epidermis of the root, and is known by the name of the *velamen radicum*.

Hypoderm.—In some cases, beneath the layers of epidermal cells are layers of wood-cells (*sclerenchyma*) or of elongated thick-walled cells, like liber-cells. These serve to strengthen the epidermis, and are called hypodermal cells. They originate from the plerome.

Cork.—The young shoots of Dicotyledonous trees and shrubs are clothed with epidermis like herbaceous plants; but before the close of the first season of growth, in most cases, the green colour gives place to brown, which is owing to the formation of a layer

of cork from the outer layers of cortical parenchyma. The surface of the corky layer is usually rough and irregular, and it peels off in laminæ periodically in certain plants, being renewed by development from the green cellular layer which it covers.

In some plants the corky layer is little developed, in others very much, as in the Cork-Oak. In the Vine and Clematis the corky layer is scarcely distinguishable after the first year's growth, as the bark breaks away, down to the liber, in stringy shreds. In *Viscum* no cork occurs; even in shoots eight or nine years old the epidermis remains, but completely consolidated by secondary deposits, as noticed above.

Cork is composed of tabular thin-walled cells, containing only air, closely arranged in rows at *right angles to the surface. The surface of wounds in soft-growing tissue is usually covered with a layer or layers of cork-cells, which form a sort of defence to the wounded tissues.* In chemical and physical properties, cork closely resembles the cuticular substances just mentioned. Cork-cells are formed from a special set of cells constituting the cork-cambium or *phellogen.* The cells divide horizontally or parallel to the surface, but always in such a manner, that of two newly-formed cells one remains full of protoplasm, with chlorophyll contents &c., while the other is transformed into a permanent cork-cell. The formation of cork, however, varies in different cases, and is sometimes of a very complex character. According to Sanio, Rauwenhoff, and Vesque, the growing cork-cells grow on the outer or on the inner side of the *phellogen* or cork-cambium, the formation being centrifugal in the former instance, centripetal in the latter. In other cases the growing cork-cells are placed on both sides of the phellogen. But in this latter case it is only the outermost cells of each layer of the phellogen which become truly corky; the inner cells in both cases retain their cellulose characteristics, and become filled with chlorophyll, forming an herbaceous envelope. Vesque has proposed that the term *periderm* be applied to the whole of the cork-cells produced by the phellogen; some of these cells, as above described, become suberified, or converted into passive cork-cells, while others retain their active character and constitute the herbaceous envelope. The periderm layers occur, not only singly, but in separate groups at different depths in the bark, causing the exfoliation of plates or rings of bark, to which the name *rhytidome* has been given by Von Mohl and Hanstein.

Lenticels are small local formations of cork-cells occurring on young shoots in the form of little warts. The cork-cells are formed beneath portions of the tissues which are decaying or dead, and which surround the cavities beneath the stomata. Similar formations are consequent upon the formation of cracks in the epiderm, the object being, in both cases, to afford protection to the denuded tissues (Trécul).

Liber.—Every fully developed fibro-vascular bundle consists, as above said, of liber, cambium or generating tissue, and wood encircled by cellular tissue. The liber (phloëm) part of the bundle is distinguished from the woody (xylem) part of the bundle by its position outside the cambium, by the larger size of its woody fibres, their different chemical properties, and especially by the presence of latticed or sieve cells, &c. The unlignified liber-cells (called also *soft bast* cells) contain albuminoid materials, proto-

plasm, &c., for the nutrition of the plant, and their walls have a cellulose reaction, become blue, not yellow, by addition of iodine and sulphuric acid, &c.

The ordinary position of the liber has been above stated, but it may also occur in the interior of the bundles, in the medullary sheath (*see* Anatomy of Stems), even in the midst of the wood. The liber, once formed, may cease to grow, or it may retain more or fewer cells still endowed with the property of dividing.

The Aerial System.—In most parenchymatous tissues of the higher plants we find the cells so disposed as to leave passages of greater or less capacity between them, which passages are usually found filled with air, apparently secreted from the contents of the cells. In imperfect parenchyma (fig. 521) these *intercellular passages* occupy a very considerable portion of the space filled by the tissue, and they intercommunicate in all directions. The spongiform cellular substance of leaves is traversed by large passages of this kind (fig. 585), expanded in many places into *air-spaces*, forming a continuous system of cavities, which are in direct communication with the external air by the stomata. When stellate cellular tissue exists (fig. 521), the air-spaces are very extensively developed.

No intercellular passages or spaces exist in young tissues; they are subsequently formed by the cells separating from each other as they expand, and excreting air into the interspaces.

Air-canals are long tubular channels, in petioles (Nymphæaceæ) or stems (*Hippuris*, *Potamogeton*, &c.), bounded by a cellular wall, and generally arranged in a definite manner in the organs in which they occur. They are sometimes continuous through long tracts of the stems or petioles (Nymphæaceæ), or they are subdivided into chambers by cellular diaphragms occurring at intervals (petioles of *Musa*, stem of *Hippuris*, *Myriophyllum*, &c.).

Lacunæ are formed by this cellular tissue being torn down and destroyed by expansion of the surrounding tissue; examples of this occur in the fistular stems of Umbelliferæ, which when young have a solid pith; but this is torn away by the expansion of the cylinder of fibro-vascular bundles, and leaves a tubular cavity. The hollow stems of Grasses, of Equisetaceæ, &c., originate in the same way.

Secretory System.—The structures in which are found the substances usually called the secretions of plants consist of *laticiferous vessels* (see *antè*, p. 513), *glands*, *reservoirs* and *canals for peculiar secretions* (resins, oils, &c.), and the so-called *milk-vessels.* They for the most part occur only in particular plants or particular organs, and present many special modifications in different Natural Orders, occurring on the surface or in the interior as single cells or in groups, or as simple or branched tubes, or in layers, but, how-

ever different in appearance, always forming and storing or conveying hydro-carbonaceous secretions.

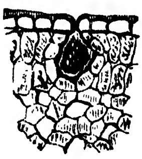
Glands are the structures of this kind most frequently met with, and they are generally connected in some manner with the epidermal tissue. Glands may be divided into *simple* and *compound*, and also into *external* and *internal*.

Simple external glands are in most cases glandular hairs; *i. e.* the terminal cell (or cells) of a jointed hair is expanded or filled with oil or other secretion. Of this nature are the glands of the foliage, flowers, &c. of many Labiatæ, Scrophulariaceæ (fig. 567, *f*), &c.

Simple internal glands are mostly isolated cells of the layer immediately subjacent to the epidermis, as in the leaves of *Begonia*, *Lysimachia vulgaris*, the petals of *Magnolia*, &c. Such glands occur also in the leaves of Lauraceæ. The *cystolithes* of Urticaceæ are related to these (p. 506).

Compound external glands are sometimes hair-like growths from the epidermis, or from the deeper tissues, from which they form outgrowths (*Drosera*). The summit or the base (*Dictamnus*, fig. 567, *a*) is sometimes developed into a cellular nodule, the cells of which either contain the secretion or surround a large central cell filled with it. Other superficial glands form papillæ of various shapes, in like manner either wholly formed of secreting cells, or with a central reservoir, as in the Hop, Begoniaceæ, Rosaceæ, Leguminosæ, &c.

Fig. 572.



Vertical section of epidermis and subjacent gland of *Ruta graveolens*. Magn. 50 diam.

Compound internal glands are commonly reservoirs surrounded by a special layer of cells, lying just beneath or sometimes rising in a dome shape a little above the surface of the epidermis. Examples of this occur in the leaves of *Ruta* (fig. 572), rind of the fruit of Oranges, Lemons, &c., leaves and stems of Hypericaceæ, Myrtaceæ, &c.

None of these glands have excretory ducts like the glands of animals. In many cases the secretions exude through the membrane, and give a peculiar character to the surface of the organs in which they are found. A very general form of secretion of this kind is the exudation of saccharine fluid from the superficial cells, very common at the base of petals and ovaries, on the stigma, and sometimes on leaves or at particular points of the lower surface of the leaves, as of *Prunus Laurocerasus*, the Laurustinus, and other shrubs. (For fuller information on these subjects, the memoirs of Trécul, Van Tieghem, and Martinet should be consulted.)

Stings are a form of glands, consisting of a long, stiff and pointed hair expanded into a bulb at the base containing the poison. This bulb is surrounded by a layer of cells derived from the epidermis, which by their tension exert a certain pressure, whence it results that when the point of the stinging-hair is broken off, the fluid is pressed out from the orifice.

Reservoirs for peculiar secretions may be regarded as a highly developed form of the internal glands. They consist of tubes

without any proper lining-wall, but surrounded by thin-walled cells filled with resin and other secretions more or less devoid of oxygen, and which are poured into the cavity lying in the midst of the parenchyma, or in the liber and wood, parallel with the fibro-vascular structures. Similar reservoirs exist in the roots of Rhubarb, in the leaves of *Aloes*, &c., in varying positions. The cells which bound the cavities sometimes grow and project into them, more or less filling them up.

Sect. 4. Internal Anatomy of Organs.

All young plants are composed of cellular tissue alone; and the Thallophytes never acquire any of the more highly developed "systems" which we meet with in full-grown Flowering Plants and the higher Cryptogamia. In the stems of the latter, the "systems" present special modes of arrangement, respectively characteristic of the great Classes. In *embryo* plants the tissues have, according to Hanstein, a three-fold origin in *dermatogen*, *periblem*, and *plerome* (see *antè*, p. 515); and these three layers are distinguishable before even the formation of the cotyledons. Famintzin considers them identical with the embryonic layers of the animal.

The more or less uniform condition of the tissues in the Thallophytes is connected with great simplicity in the physiological processes of vegetation and growth; while in the higher plants the difference of internal organization is accompanied by important differences in the modes of development of the axis. It would cause us to exceed our limits very widely to enter into minute details of the internal structure of the organs of vegetation of plants generally; but it is requisite not only to give a general sketch of the plan of organization, but to describe some of the more important modifications met with in the higher Classes.

Structure of Stems.—As a general rule, plants possessing stems and leaves exhibit in their *stems* a definitely arranged fibro-vascular system, the bundles of which send off branches, or pass off themselves entirely, to form the ribs and veins of the *leaves*. The young stem is made up of wood-cells and vessels, placed the one within the other, superposed in rays and surrounded by connecting cellular tissue. The same axial system furnishes below, directly or indirectly, the bundles which constitute the woody central mass of *roots*, in which originally the liber and the vessels are placed side by side.

Mosses.—The simplest form of the fibro-vascular system is seen in the Mosses (p. 431), where a cord of prosenchymatous tissue runs up the centre of the thread-like stem, and in some cases sends off branches to the leaves.

Lycopodiaceæ.—In the Lycopodiaceæ (p. 423) the axis of the stem is occupied by one or more parallel fibro-vascular bundles, containing spiral

and scalariform vessels, surrounded by parenchyma. The bundles are regularly developed onwards with the growth of the point of the stem, sending off lateral branches of spiral vessels where leaves arise, but undergoing no change after the internode in which it lies is once formed.

Equisetaceæ.—In the Equisetaceæ (p. 417) a ring of isolated fibro-vascular bundles exists in the periphery of the aerial stem, surrounded by liber-cells and parenchyma; these, again, are closed bundles, and grow only at their points as the stem elongates. The constituent vessels are spiral or annular. The epiderm, and specially its hypoderm, fibres are highly developed. The Equisetaceæ are the only plants known whose buds originate deep in the substance of the stem.

Filices.—In the Ferns (p. 419), where the stem acquires greater dimensions, we find a number of fibro-vascular bundles standing in an irregular circle, surrounding a central cellular axis, and externally surrounded by a kind of rind (liber) containing sieve tubes. The bundles do not run straight up the stem, but in waved curves; and they anastomose laterally and separate again, leaving wide passages of communication between the central parenchyma and the rind (fig. 573). The branches of the bundles going to supply the leaves are given off at the anastomoses of the main bundles; and the bundles running into the (adventitious) roots arise at similar places. The bundles of the stem have only indirect connexion with those that pass to the leaves, so that in leafless parts of the stem the arrangement is the same as where there are leaves present. These bundles are closed, and therefore the stems never alter in dimensions when once formed. In cases like that of *Angiopteris evecta*, where the stem is reduced to very small proportions, there are, according to Mettenius, three zones of fibro-vascular bundles, one within the other, and connected by intervening net-like bundles. It was formerly supposed that vessels of the scalariform type were the only ones that occurred in Ferns; but it is now well known that spiral and annular vessels also occur, especially in the younger portions.

All the above forms of the stem are characterized by having their fibro-vascular bundles when complete destitute of cambium, hence called closed (p. 515). They are developed only at the point. From this circumstance, these higher Cryptogamia are often called *Acrogens*, or *Acrobrya* (point-growers).

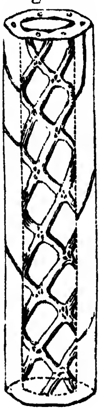
Monocotyledons.—The stems of Monocotyledonous plants have a very different organization from the above. The most striking peculiarity, at first sight, is the isolation of the fibro-vascular bundles, which, as a rule, anastomose but slightly in any part of their course through the stem, and are scattered singly in the parenchyma of the stem (fig. 574). Another important circumstance is, that they pass entirely into the leaves at their upper ends (fig. 575, *a*), while at their lower extremities they approach the surface of the stem and anastomose with their fellows to form a more or less developed fibrous network, separating the rind or cortical parenchyma from the central fibrous part of the stem. It is from this network that the fibro-vascular axes of the (adventitious) roots are derived (fig. 575, *b*).

The stems of Monocotyledons are very generally herbaceous, and thus present very important varieties of form, arising from non-development of

internodes, according to regular plans. These modifications disguise the structure; but it may be readily understood by means of diagrammatic illustrations of some of the principal forms.

Fig. 575.

Fig. 573.



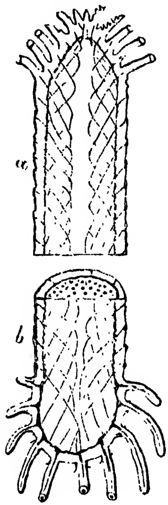


Fig. 574.

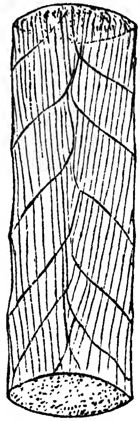


Fig. 573. Diagram of the arrangement of the fibro-vascular bundles in the stem of a Tree-fern.

Fig. 574. Diagram representing the arrangement of the fibro-vascular bundles in a Palm-stem.

Fig. 575. Another diagram, representing the upper (*a*) and lower (*b*) extremities of a Monocotyledonous trunk, with its fibrous layer, where the stem-bundles terminate and those of the root commence, enclosed by a cortical layer.

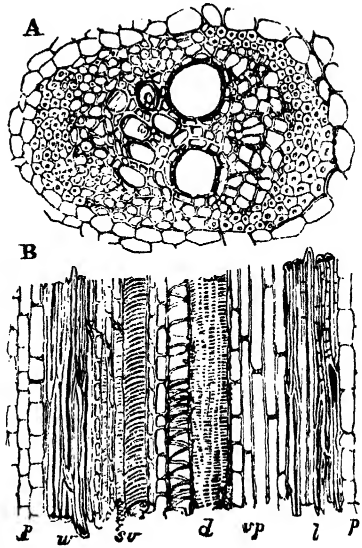
The fibro-vascular bundles of Monocotyledons (fig. 576) being of the *definite* or *closed* kind (p. 515), they acquire their full development in each internode before the leaves to which they belong fall; and hence the stems of this class do not increase in diameter as a general rule, but have a columnar character when they form woody trunks. But there are exceptions to this rule.

It has just been stated that the fibro-vascular bundles terminate below, near the periphery of the stem, and there form a more or less evident network of fibres; this network constitutes a kind of sheath round the general mass of the stem, and is itself covered by a more or less developed *rind* or cortical parenchyma (fig. 575, *b*). The tissue in the region of the fibro-vascular network, or *fibrous layer*, remains in most cases in the condition of cambium, as we see adventitious roots readily formed in this situation. In *Dracæna*, *Yucca*, and some other woody Monocotyledons the stem becomes increased in thickness with the age of the tree, by the formation of layers of liber-like prosenchyma in this *fibrous layer* pushing

the rind outward. The original central fibro-vascular system of the stem remains unaltered.

The region, at the junction of the central and cortical parenchymas, where the fibro-vascular bundles terminate should perhaps be called a *cambium*-region, since the cellular tissue situated here retains its developmental power in many cases. The essential difference between this and the cambium-ring of Dicotyledons depends on the fact of its not coinciding, in a parallel arrangement, with the cambium-region of the fibro-vascular bundles, but with the *extremities* of the bundles, which always remain isolated from each other. The successive layers of fibrous structure in *Dracæna* &c. are formed in like manner of isolated bundles imbedded in parenchyma; they are unconnected with the old bundles of the primary axis, but are continuous above with the *lower ends* of bundles belonging to the *branches* occurring in these stems.

Fig. 576.



Monocotyledonous fibro-vascular bundle (from the spadix of *Phœnix dactylifera*). A. Transverse section. B. Vertical section; *p*, parenchyma in which the bundles lie; *w*, wood-cells; *s v*, spiral vessels; *d*, reticulated ducts; *v p*, *vasa propria*; *l*, liber-cells. Magn. 100 diam.

The stems of herbaceous Monocotyledons have the fibro-vascular system always in the form of "stringy" fibres imbedded in succulent parenchyma; and in those perennial stems of the Class which acquire a solid woody structure the ligneous character depends, not on the fibro-vascular system, but on the general parenchyma of the stem having its cells lignified (sclerenchyma), of which we have examples in the Cocoa-nut and other Palms, in the Bamboo, &c.

The *rind* of the Monocotyledonous stem, totally different from true *bark*, is generally little developed. On herbaceous stems it is a mere epidermis; but on fleshy rhizomes it sometimes acquires considerable thickness, and is then found to be composed of spongiform parenchyma, with large air-cavities, the whole bounded externally by a few layers of tabular parenchyma with a corky outer surface.

A certain number of forms occur aberrant from the type above described. In *Aloe* the fibro-vascular bundles are so arranged as to form a kind of cylinder, separating a central from a cortical parenchyma. In the Smilaceæ, Dioscoreaceæ, and some other Orders, the rhizomes imitate still more the Dicotyledonous arrangement; for not only do the bundles stand in circles, they do not pass wholly off into the leaves, but run continuously through the structure. Still there is no periodical resumption of activity

in the bundles, as in the Dicotyledons. In *Tradescantia*, and in the Grasses also, anastomoses of the isolated fibres take place at the nodes of the stem.

Dicotyledonous Stems.—The stems of Dicotyledons, and of Conifers which agree in the main points, are at first of very simple structure, almost resembling those of the Ferns; but their fibro-vascular bundles being of the open or *indefinite* kind, capable of lateral growth by addition of new elements season after season in their outer regions, the full-grown stems depart widely from the preceding types.

Fig. 577.

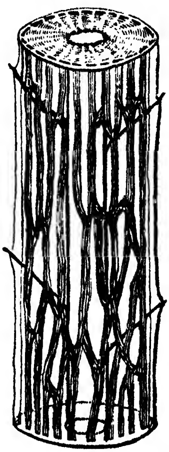


Diagram of the arrangement of the fibro-vascular bundles in a yearling stem of a Dicotyledon.

For purposes of comparison, attention must be confined to shoots or stems of Dicotyledons in their first year of growth, as the formation of annual layers is a phenomenon to which there is nothing correspondent in the other Classes (excepting Conifers).

When a young herbaceous stem of a Dicotyledon is cut across, we find the fibro-vascular bundles standing in a circle round a central parenchymatous mass, the pith, and enveloped by a cellular rind (fig. 577). The bundles run in tolerably straight vertical courses and anastomose freely; a certain number of bundles are distributed to each leaf.

As the stem increases in age, each fibro-vascular bundle forms a wedge-shaped mass of wood (fig. 578) by development of the inner part of the cambium-region, and at the same time a layer of liber at the extreme outer side, next the bark. At the close of the first season, therefore, we have a central *pith* (fig. 578, *p*), immediately bounded by the vascular portion of the bundles (called the *medullary sheath*) (*m s*), from which pass the vessels to supply the leaves; next come the wedges of *wood* (*w*), formed of prosenchyma (*pr*) and ducts (*d, d*) in most Dicotyledons, of prosenchyma alone in Conifers, which passes into the *cambial* or generating layer (*c*); and this is continuous outside with the *liber*-bundles (*l*), corresponding to the wedges of wood: the liber-fibres, like the inner vascular elements, send branches to form part of the ribs of the leaves.

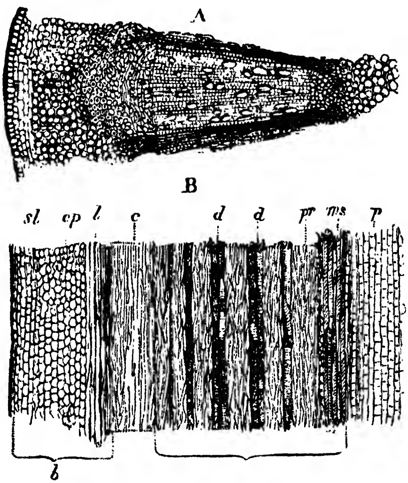
The fibro-vascular bundles, standing side by side, do not become absolutely united, but are separated by thin plates of compressed cellular tissue, running out from the pith to the cortical parenchyma; these plates are called *medullary rays* (fig. 579).

The liber-portions of the bundles are associated with rows of clathrate cells (p. 487), and frequently with latex-canals (p. 513), and they are surrounded by a layer of parenchyma, composed of cells filled with sap and containing chlorophyll, the herbaceous or *cellular envelope* (fig. 578, *c p*); and this is protected externally by the dry *suberous layer* (*s l*), which succeeds to the epidermis when the herbaceous shoot acquires a woody character.

Modifications.—Many special modifications of the above type are met with in Dicotyledons. In the Piperaceæ there is a kind of double concentric circle of fibro-vascular bundles, the inner circle supplying the

leaves, but not possessed of a cambium-region; while the outer circle is of the ordinary open or unlimited character. In the Sapindaceæ, Malpighiaceæ, and some other Orders, part of the fibro-vascular bundles remain separate from the principal circle, and lay the foundation of a number of secondary cylinders of wood enclosed by a common bark; this phenomenon may be well observed in *Calycanthus*, where a square form of the stem results from four fibro-vascular bundles remaining free from the central cylinder of wood in this way. In the Nymphæaceæ we find a very aberrant condition: the fibro-vascular bundles, formed of vessels and parenchymatous cells alone, without wood, are quite isolated, destitute of *cambium*, and form a complicated interlacement closely resembling that occurring in Monocotyledons—there being no distinction of pith and medullary rays, and no bark.

Fig. 578.



Dicotyledonous fibro-vascular bundle (Plane-tree) of one year's growth. A. Transverse section. B. Vertical section; *s l*, suberous layer of the bark; *c p*, cortical parenchyma: *l*, liber; *c*, cambium-region; *d*, ducts lying in the prosenchyma, or wood-cells, *pr*; *m s*, medullary sheath of spiral vessels; *p*, pith. The structures connected by *b* belong to the bark, those marked *w* to the wood. In A, the bundle is seen to be bounded on each side by a medullary ray, running from the pith to the cortical parenchyma. Magn. 50 diam.

A still more frequent source of diversity lies in the varied nature and mode of arrangement of the elements of the *wood*. In the Plane (fig. 578) we see the spiral and annular vessels succeeded by a body of prosenchyma, in which are scattered large pitted ducts. In the Hazel and Alder these ducts are far more numerous, as they are also in the Lime. In the Oak the prosenchymatous cells are very small, and become greatly thickened, but the ducts are large. The Box has very small and dense prosenchyma-cells and few and small ducts. In the spongy wood of the Bombaceæ the prosenchyma is almost wholly replaced by thin-walled parenchyma.

In the Coniferæ there is a total absence of ducts, the wood being formed exclusively of prosenchyma with the peculiar *bordered pits* (fig. 537), or, as in *Taxus*, with both pits and a spiral fibre (fig. 542).

Annual growth of Rings.—With the commencement of a second season of growth, a Dicotyledonous stem begins to acquire its especial peculiarities. When the buds open to produce new shoots, cell-division recommences in the cambium-region of the old bundles, and an additional layer of wood is added gradually during the season to that formed the year before. Season after season this process is repeated, and thus the cross sections of the stems present a series of concentric laminæ of wood corresponding to the number of seasons during which the stem has existed (figs. 579 & 580).

Fig. 579.

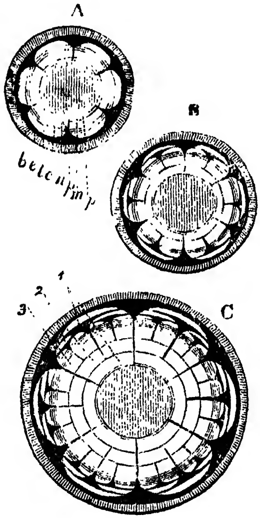
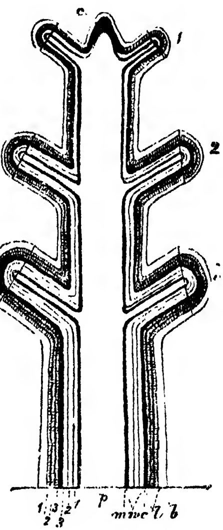


Fig. 580.



lary rays; *l*, liber; *c*. cambium-region; *n*, wood; *p*, medullary rays; *m*, medullary sheath of spiral vessels; *p*, pith. The figures to C, 1, 2, 3, mark the wood and liber belonging to the 1st, 2nd, and 3rd year.

Fig. 580. Diagram of a vertical section of a Dicotyledonous stem 3 years old, with 3 branches marked 1, 2, 3, indicating the age in years of the branch and the internode below it. The figures below denote the ages of the layers of liber and wood; *p*, pith; *c*, cambium; *m*, medullary sheath; *w c*, layers of wood; *l*, layers of liber; *b*, cellular and corky layer of bark.

The concentric lamellæ of wood in Dicotyledons are really *annual rings* in most trees of temperate climates. In the tropical trees it frequently

happens that more than one ring is formed annually. In our own trees an interruption to the vegetation, such as is caused by an accidental *defoliation* during the summer, produces additional annular markings. In the common Beetroot several rings are produced in one season.

In some tropical trees (Malpighiaceæ) the concentric circles are not very clearly marked; in others they are even separated by a distinct layer of parenchyma. In the Bignoniaceæ it is common to find the wood divided into four large portions, separated by wedge-shaped cortical structures, giving in the horizontal section the form of a cross. The old stems of such plants as the Sapindaceæ &c., above referred to, with isolated bundles outside the central woody cylinder, acquire very anomalous forms with age, since each collection of fibro-vascular bundles is developed annually in its cambium-region, and hence the stem assumes the appearance of several stems enclosed in a common bark. In Cycads more than one year is required to complete a woody zone; thus, in very old stems of Cycads, only a few rings are seen surrounding a voluminous pith.

Heart-wood and Sap-wood.—As woody trunks increase in size, the older parts of the wood frequently go on increasing in density by the formation of *secondary* layers in the cells of the prosenchyma; thus the old central wood becomes more solid, forming what is called the *duramen* or *heart-wood*, which is sometimes deeply coloured by chemical changes or secretion of various substances, as we see in Ebony, Lignum Vitæ, &c. The young external layers of wood, in which the ascending current of fluid passes freely, is called the *alburnum* or *sap-wood*. The chemical and physical changes which take place as the sap-wood passes into the state of heart-wood have been previously alluded to.

Origin of the Fibro-vascular Bundles.—The fibro-vascular systems of the branches of Dicotyledons originate independently in the bud from the procambium, but soon become blended with those of the parent axis, with which their layers of increase become uninterruptedly continuous. When a branch is broken off short, leaving no buds upon it to continue its growth, it becomes surrounded and ultimately entirely enveloped by the succeeding annual layers of wood, and in this way forms a "knot." The numerous small knots of the wood of *Pinus sylvestris* arise from certain of its branches being broken off while small.

Pith.—The *pith* or *medulla* consists of parenchymatous tissue, filled with nutrient matters, stored up for the use of the growing tissues. It is of most service in young twigs, and becomes more or less inert in after-life, and often disappears as the wood grows. It exists either as a continuous cylinder, or is broken up into disks separated by cavities one from the other, as in the Walnut. The cells of the pith contain starch, or crystals, or simply air. In some cases some of the cells of the pith retain their vitality longer than others, so that there is an admixture of living and dead cells; and in this way the differences in the pith may even serve to distinguish certain genera one from the other (Gris). Occasionally it is more or less completely lignified.

Medullary Rays.—The *medullary rays* (fig. 579, A) which separate the primary bundles are developed in the cambium-region with the yearly layers of wood, and always extend to the cortical parenchyma; in the layers of successive years the new elements of the wood separate into

parcels divided by *secondary medullary rays* (fig. 579, B, C), which are repeated in each successive season. The course of the fibro-vascular bundles being slightly sinuous, from their lateral anastomoses, the medullary rays have, singly, no great vertical dimensions; and their transverse diameter varies in different cases. Their cells become lignified in heart-wood.

Liber.—The *liber* (for an account of the construction of which see *antè*, p. 517) is usually formed in successive thin laminæ composed of slender laterally anastomosing bundles of liber-cells; and in some plants these laminæ are separated by layers of parenchyma or periderm, so that the liber-structure of old stems may be split into its annual layers. In some stems the liber ceases to grow after the first season.

The *bast* of which Russia matting is made consists of the separate liber-layers of the Lime-tree. The "lace" of the Lace-bark tree (*Lagetta lintearia*) is the liber, and that of other trees of the Order Thymelaceæ is used for tying up bundles of cigars &c.

The Herbaceous Envelope.—The *cellular* or *herbaceous envelope* (fig. 578, *ep*) is generally in an active condition of vegetation during the growing-season, since its tissue must increase laterally (tangentially to the stem) to allow of the increasing diameter, while it produces the new suberous structure on the outside.

Cork-layers.—The *suberous layer* differs much in its condition in different trees. The general construction has been alluded to at p. 522.

The Structure of the Root has of late attracted much attention from Nägeli, Reinke, Janczewski, Van Tieghem, and others. It is only by studying the mode in which the originally homogeneous cellular mass of the root breaks up into distinct layers and assumes a different form and arrangement of its constituent cells that the structure can rightly be understood. The simplest idea of the root is that of a mere unicellular thread, such as we meet with in the lower Thallogens, and also in the shape of the root-hairs which are produced from the epidermis of more highly organized roots. Physiologically, viewing the root merely as an organ of absorption, this type of root is all important. But in most plants the root is something more than an organ of absorption. It is a laboratory, in which nutritive matters are moved from place to place or are stored up for future use, so that roots of this character have much of the functions of the stem. Accordingly we find, in roots of higher organization, considerable difference of structure, varying also in the different groups of plants.

The roots of vascular plants may be defined as outgrowths from the interior of the stem provided with a root-cap (*pileorhiza*), but as a rule never producing leaves or buds, and growing in length only near the point beneath the cap.

The general structure of the roots of vascular plants may be defined as consisting of an epidermis, bounding a cortical paren-

chyma, in which is plunged a central cylinder. The epidermis will be spoken of hereafter.

The Cortical Parenchyma is wholly cellular, and may be generally subdivided into two zones, an outer and an inner. The cells of the outer zone increase from within outwards (centrifugally), decrease in size towards the outside, and are so closely packed as to leave no intercellular spaces. The cells of the inner zone of the cortical parenchyma increase from without inwards (centripetally), and decrease in size from without inwards. They are disposed in radiating series or in concentric zones, and have intercellular spaces.

The Protecting Sheath.—This, the *gaîne protectrice* of the French, the *Schutzscheide* of the Germans, was first pointed out by Caspary. It is a special layer of cells, forming the innermost layer of the cortical parenchyma and separating it from the central cylinder. The cells of the protecting sheath are marked on their sides by transverse folds or ridges, the ridges of one cell fitting into corresponding furrows of its neighbour, so that the cells are "dove-tailed" into one another. In longitudinal section these undulations of the cell-walls give an appearance as of the rounds of a ladder; in transverse section the appearance is given of very small oval dark spots in the middle of the lateral boundaries of the cell.

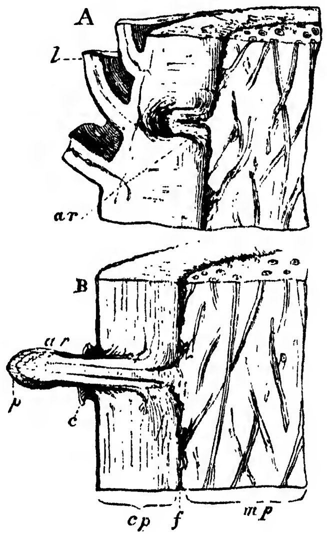
The Central Cylinder (Pericambium) is originally a mass of pleroma or growing cellular tissue: the outermost layer of this develops into a special layer of *pericambium*, which is thus in immediate contact with the protecting sheath on the outer side, its cells being so arranged as to alternate with those of the sheath. Thus one cell of the pericambium comes between two of the sheath, and so on. Hence the layer is readily recognizable under the microscope. The central mass of plerome forms the vessels which are developed centripetally and alternately with bundles of bast or liber-cells, also developed centripetally. The untransformed cellular tissue surrounding the vessels and bast-cells is called the connecting tissue. Roots of this character, then, differ especially from the stem in having their bast or liber-cells alternating in position with the vascular bundles proper, not placed external to them.

Roots of Vascular Cryptogamia.—The structure of the roots of the higher Cryptogams is identical in the main with that just described; when once the primary structures are completed no further change takes place. The new rootlets originate from the inner layers of the cortical parenchyma. The roots of Equisetaceæ have no pericambial layer.

Roots of Monocotyledons.—The general structure is the same as that of the Vascular Cryptogams, the rootlets originating from the pericambial

or rhizogenous layer opposite to the vessels (fig. 581, A, *a r*), except in Grasses, where they originate opposite the liber-bundles. The anatomy may be easily studied by tracing the development of the adventitious roots on the rhizomes of Rushes, Flags, and other plants of this Class. The roots originate in the region where the fibro-vascular bundles of the stem terminate (and frequently form a fibrous plexus). They are at first wholly cellular, and we may distinguish in them three parts,—a woody axis, which soon becomes continuous with the fibro-vascular plexus; a cortical parenchyma, continuous with the *inner* part of that of the parent stem; and a kind of conical hood of rather dense cellular tissue, enveloping the end of the root. As the root grows it pushes the hood forward, which breaks down the cellular tissue before it, and finally appears externally. When the epidermis is ruptured in this way, it presents a circular free edge standing up slightly like a collar around the base of the free part of the root: this is called the *coleorhiza* (fig. 581, B, *c*) by some authors. The conical hood upon the apex of the root forms the *root-cap* or the *pileorhiza* (fig. 581, B, *p*), and is more or less persistent in different cases; in aquatic plants it becomes greatly developed, as may be seen in the Duckweed (*Lemna*), where it forms a long sheath, appearing as if slipped over the end of the rootlet. The focus of development of the root is within the *pileorhiza*, which is pushed forward by the continual development of cells just behind the apex.

Fig. 581.



Development of adventitious roots in *Sparganium*. A, B. Fragments of a rhizome with cortical parenchyma (*c p*), fibrous layer (*f*) where the fibro-vascular bundles terminate, and central region (*m p*) in which the bundles run. A, *a r*, shows an adventitious root arising from the cambium tissue at the outside of the fibrous layer: in B the more advanced root (*a r*) has emerged, leaving a ragged collar or coleorhiza (*c*), and having a root-hood or pileorhiza on its extremity.

The *pileorhiza* may be compared to a kind of shield or guard to the tip of the root, protecting the nascent tissue, by the expansion of which it is pushed forward, itself always possessing a certain solidity which enables it to penetrate between the particles of the soil.

In a cross section of the root of a Monocotyledon we see the centre occupied by prosenchymatous tissue, with a circle of vessels around it; the whole enclosed by regular parenchyma, sometimes by liber-cells, and covered by an epidermis. The ring of vessels spreads out into a kind of rosette at the base, and anastomoses with the extremities of the fibro-vascular bundles of the stem in the fibrous region. Secondary adventitious roots are formed in the same way in the roots, originating imme-

diately upon the vascular ring and breaking through the cortical parenchyma.

The woody adventitious roots of arborescent Monocotyledons differ only in the greater development of the fibro-vascular structures; and they emerge from the stem (Palms) in the form of thick conical shoots.

When adventitious roots, like those just described, die away, they decay down to their very origin, and leave a scar in the form of an orifice surrounded by the ragged coleorhiza.

In the thickened adventitious roots of *Asparagus*, which perform the function of *tubers*, the parenchyma is greatly developed. In the tuberous roots of Orchids (figs. 21 & 22) the central woody axis becomes irregularly expanded into parenchymatous tissue driving the vessels out nearly to the periphery, so that the characteristic structure is greatly disguised. The aerial roots of the epiphytic Orchids have the growing extremities clothed by several layers of a parenchymatous tissue, in which the cells are characterized by delicate open spiral-fibrous secondary layers.

Roots of Dicotyledons.—In these plants the root has at first the same structure and arrangement of its elements as in Cryptogams and Monocotyledons, the rootlets being formed opposite the vessels from the pericambial layer. A great difference, however, shows itself in a secondary

Fig. 582.

Fig. 583.

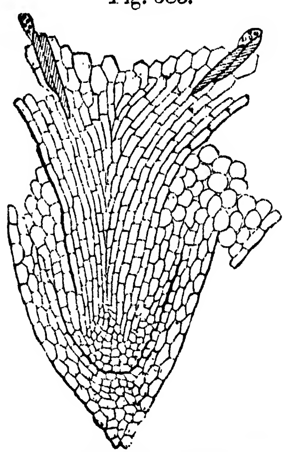


Fig. 582. Extremity of the root of a germinating Turnip, with root-hairs. Magn. 30 diam.
Fig. 583. Longitudinal section through young root, showing the root-cap.

formation of liber and vessels, which enables the roots to thicken and even to form concentric zones exactly as in the stem. In the early stage of the Dicotyledonous roots the bundles of liber-cells and the bundles of vessels are, as in the other groups of plants, alternate with each other, but a secondary formation of cambium-cells takes place on the inner side

of each of the primitive liber-bundles. This secondary cambium grows both on its outer and its inner surface, forming ultimately on the outer side liber-cells, on the inner side vessels exactly as in the case of the Dicotyledonous woody bundles. In general terms, then, it may be said that the Dicotyledonous root consists of a cellular mass encircled by cortex. In the central cellular mass are formed two or more sets of vessels and of liber-cells, each distinct from the other and alternating one with the other (fig. 583). After this primary stage of growth is completed, a secondary development of fibro-vascular bundles, with the liber outside and the vessels inside, takes place on the interior of the primitive liber-bundles, which latter are therefore pushed outwards. Ultimately, then, there are two or more radiating plates of primitive vascular tissue separated by cellular tissue from a series of radiating plates, consisting of liber and vessels.

Great variations occur in different plants in the number and exact disposition of the bundles &c., for an account of which the original memoirs of the authors above cited must be consulted.

In the adult state the *axial* root of Dicotyledons, being a direct continuation of the stem, displays a circular group of fibro-vascular bundles as in the ascending axis; but these mostly converge at the point of junction of stem and root (*collar*), so that the central axis of parenchyma, the *pith*, is usually absent, the medullary rays remaining as in the stem. The roots of Dicotyledons increase in diameter by annual layers of wood formed in the fibro-vascular bundles, these, however, being less regular in their arrangement than those of the stem on account of the tortuous course of the roots; hence while the wood of the roots is often useful for ornamental purposes, it is comparatively valueless for carpenters' uses. The branches of the axial root are originally growths from the apex of the root, thrown off to the side, as it were, and their woody axis is derived from a division of that of the main root.

The radicle of a germinating Dicotyledon has its root-cap, and grows in the same way as that of the Monocotyledons, by development of cells just behind the apex (figs. 582, 583).

Root-hairs.—Young roots are covered by a delicate epidermis; and the cells of this are abundantly produced into hairs in many plants (fig. 584), especially in those growing in light soils; these fibrils are deciduous, the delicate epidermis (which is always destitute of stomata) being gradually converted into a corky layer.

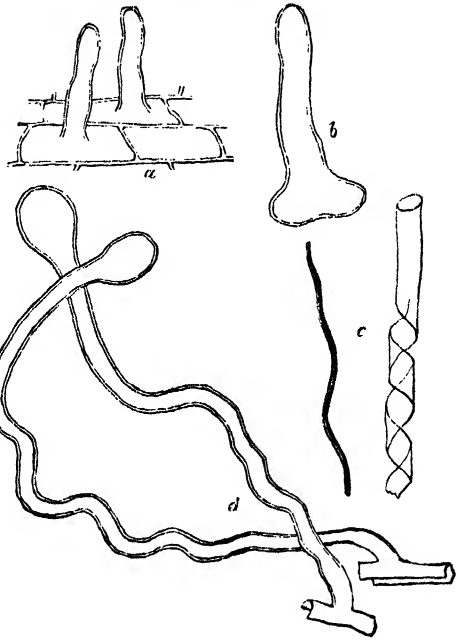
Adventitious Roots are very common in Dicotyledons, especially the herbaceous perennial kinds, and they alone can exist on plants raised from *cuttings* &c. of stems. The roots originate much in the same way as those of the Monocotyledons, appearing first as cellular cones in the region adjacent to the cambium-layer, with which the fibro-vascular structure soon becomes confluent. They break through the rind, with a coleorhiza, and protected by a pileorhiza, just as in Monocotyledons; but when once formed, they appear to branch in the same manner as the axial root, and not by the formation of secondary adventitious roots.

Trécul states that the structure of adventitious roots differs according to the part of the stem whence they emerge. If, for instance, they originate opposite a fibro-vascular bundle, as in *Nuphar*, the centre of the

root is occupied by a bundle of fibro-vascular tissue; if they spring from the stem opposite the pith or cellular tissue between the vessels, then the centre of the root is likewise cellular. In Cryptogams, according to Nägeli, the roots always originate opposite a fibro-vascular bundle.

The primary form and disposition of the roots depend in a measure on the form of the terminal cells and on the direction of the partitions by which they are divided—lengthwise, horizontal, or oblique.

Fig. 584.



a, epidermal cells; *b*, *c*, *d*, root-hairs.

Tuberous Roots of herbaceous Dicotyledons present several modifications in the arrangement of the structures. In the Carrot and Parsnep the fibro-vascular ring has its component parts much separated by the great development of the medullary rays and masses of parenchyma replacing the ordinary prosenchyma of woody roots, so that the fibro-vascular structure has a deceptive resemblance to that of Monocotyledons; and the cortical parenchyma, again, is greatly developed, so as to form a thick fleshy rind. In the Turnip the cortical parenchyma is little developed, and the mass of the fibro-vascular bundles lies immediately under the rind, the inner vascular parts of the bundles being split up, as it were,

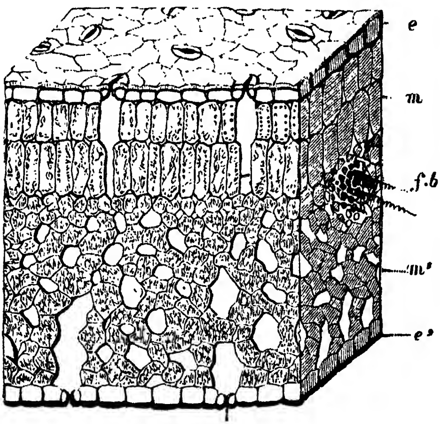
into a row of fibres radially arranged and imbedded in a great quantity of lax parenchyma. The fibro-vascular bundles converge at the "collar," and then separate again to surround the *pith* of the stem; they also converge again towards the point of the root. These so-called roots are more nearly allied to the stem, and are, indeed, hypocotyledonary stems.

The structure described under the name of *spongioles* has no existence in nature. The error has probably arisen from the appearance presented by the *pileorhiza.*

Old roots of Dicotyledons present a dense heart-wood like the trunks, passage of fluid taking place through the outer layers. When the older parts of roots are exposed to the air by removal of soil, they acquire a thick corky *periderm.*

The general structure of the root of Gymnosperms is like that of Dicotyledons, except that there is no dermatogen, the outer layer of the periblem becoming transformed into epidermis.

Fig. 585.



Projection of a fragment of the leaf of the Turnip, constructed from sections made in various directions, and magn. 100 diam.: *e*, epidermis of the upper surface with its stomata; *e'*, epidermis of the lower face; *s*, stomata, cut through, opening into intercellular cavities; *m*, close parenchyma (palisade cells) of the upper part of the leaf; *m'*, loose and spongy parenchyma of the lower part; *f.b*, the cut end of a fibro-vascular bundle forming one of the veins of the leaf.

Structure of Leaves &c.—The plan of construction of the leaves and of the other appendicular organs of the stem is in the main identical throughout all cases; but there is very considerable variation within the limits of the general type. The essential character of the anatomy of a leaf is, that it is an expanded layer of parenchyma clothed over its whole surface with epidermis, and furnished, according to its degree of development, with a more

or less extensive and complicated framework of fibro-vascular bundles.

In the leaf of the Turnip, for example (fig. 585), we find an upper (*e*) and lower (*e'*) epidermis, with an intermediate mass of parenchyma (or merenchyma, *m*, *m'*), rather close in the upper part, whence the name *palisade tissue*, and spongiform in the lower part. The epidermis is studded with stomata (*s*), which open into intercellular spaces communicating freely throughout the spongy tissue, and, further, through the petiole, with the intercellular passages in the stem. The fibro-vascular system (*ribs* and *veins*) runs through the lower lax parenchyma (fig. 585, *f. b*), and consists of bundles of spiral vessels and liber, the former continuous with the medullary sheath and youngest part of the vascular axis of the stem, the latter continuous with the liber-bundle outside the cambium. The primary ribs in most Dicotyledons contain much liber, and thus become very thick, so as to project from the lower face of the leaf. They have a structure almost precisely like that of a small branch.

Great differences result from the different degrees of development of the spongy portion, as may be seen by comparing the leaf of the Lilac with that of the Aloe or *Mesembryanthemum* &c. The degree of consolidation of the epidermis by the formation of thickening layers is the principal source of difference in the degree of solidity of leaves.

Submerged leaves of aquatic plants have no stomata nor any extensive intercellular system; the epidermis is also little developed, and there is commonly a total absence of fibro-vascular tissue: hence the delicate and perishable character of these organs.

The leaves and other appendicular organs are especially the seat of the glandular and analogous epidermal structures.

Structure of Petioles.—The petioles usually consist of a mass of parenchyma, surrounded by epidermis and traversed by fibro-vascular bundles arranged in a more or less semicircular manner, the spiral vessels being uppermost, corresponding to the medullary sheaths. When cylindrical the bundles form a complete circle, and the structure is then undistinguishable from that of a young branch, on which account the ordinary leaf has been regarded as a branch the upper portion of whose vascular tissues are suppressed or depauperated (C. de Candolle).

Fall of the Leaf.—The fall of the leaf, as of the fruit, and in some cases of the branches (as in *Taxodium*, &c.), is effected by the gradual formation of a layer of thin-walled cells across the petiole, at right angles to the direction of the other tissues, and which thus ultimately separates the inert leaf from the living stem as by a knife-blade.

Structure of the Floral Organs.—Bracts, sepals, petals, &c. are organized on the same plan as leaves, their epidermis frequently presenting raised conical cells and having stomata. The tissues of these organs are more delicate, the fibro-vascular structures being almost exclusively formed of spiral vessels. The parenchyma of petals contains fluid colouring-matters instead of chlorophyll.

In the parenchyma of the floral organs of coloured structures, the cells are filled with fluid colouring-matters of various tints, the depth of colour

depending on the greater or smaller number of layers of colour-cells beneath the epidermis, the tints differing accordingly as cells containing colouring-matter of different hues overlie one another.

Structure of the Anther, &c.—Stamens and pistils are composed of rather regular parenchyma with a delicate epidermis, and fibro-vascular ribs more or less developed in different cases.

The structure of the *anther* is somewhat complex, varying not only in different plants but also in different stages of growth. At first consisting of cells of about the same size and form, it subsequently presents a central mass devoted to the formation of the pollen (see under Physiology of Reproductive Organs). This central mass is overlain by three layers of cells: first in order going from within outwards is the *endothecium*, constituted by a single layer of delicate cells of a different size and shape from the rest, and usually disappearing as the pollen-grains are matured. These cells apparently contain nitrogenous contents, supposed to be applied to the nutrition of the pollen-cells during their growth. This layer is persistent in the case of anthers opening by pores. Succeeding the endothecium are one or more layers of permanent cells, some of which contain spiral fibres. These cells constitute the *mesothecium*. The fibrous cells vary in number and situation in different plants, and are sometimes entirely absent, as in the case of anthers opening by pores; hence they are supposed to act hygrometrically in the dehiscence of valvular anthers. The third layer of the anthers is of an epidermal character, and is called the *exothecium*. The connective has the general structure of the filament; sometimes, as in some Lilies, it contains fibrous cells. Each cell of the anther is partly subdivided by cellular projections from the connective; to these processes M. Chatin gives the name of *placentoids*, being of opinion that they contribute to the nourishment of the pollen.

Pistil.—The pistils and fruits have, for the most part, the general structure of leaves. Some of their fibro-vascular bundles run along the placentas and give off spiral vessels through the funiculus to terminate at the chalaza of the ovule. The style has usually in the centre a quantity of loosely packed, cylindrical, elongated cells, constituting the *conducting tissue* for the pollen-tubes. The stigmatic cells are devoid of epidermal covering, and hence present the form of partly detached prominences or papillæ.

Ovules, Seeds.—The coats of the ovule, as well as the nucleus, are described as wholly cellular; frequently, however, the vascular tissue, instead of ceasing at the chalaza, is prolonged upwards into the coats, as may be seen in the testa of many seeds, *e. g.* Almond, Walnut, Cycas, &c. Great changes take place in the nature and arrangement of the cells as the ovules ripen into the seeds. The disposition of the cells of the outer investment of seeds is often very beautiful and characteristic.

In the ripening of the fruit the organizing tissues, which carry on the growth of the organ, are situated between the inner epidermal layer and the fibro-vascular zone, as in the case of leaves. Moreover the fibro-vascular bundles are arranged, as in the leaf-blade, with reference to a surface, and not in a cylindrical disposition as usually in stem-organs.

Thalamus.—The anatomy of the thalamus or receptacle corresponds with that of the stem. Hollow receptacles, like those of the Rose or of the Apple, in which the carpels are enclosed or imbedded, have essentially a stem-structure, their cambium-layer being placed between the fibro-vascular zone and the outer epidermis.

Anatomical and organogenetic investigations show that inferior ovaries (p. 130) are really cases of adhesion of the imbedded carpels to the expanded upper extremity of the thalamus.

The parts of the flower, and especially the carpels, show many minor variations of structure not clearly referable to either the leaf or the stem type of structure; and from these, as well as from numerous exceptional and transitional cases, it must be assumed that the distinction between leaf and axis is not absolute but arbitrary, though it must for convenience' sake be retained.

CHAPTER II.

PHYSIOLOGY OF VEGETATION.

Sect. 1. General Considerations.

Plant Organization.—The organization of plants is regulated by a series of laws which exhibit different degrees of generality.

The most general law of all is that under which protoplasmic substance assimilates inorganic or, more rarely, organic matter, and produces the closed cellular sacs called vegetable cells. This affects all vegetable structure whatsoever. Animal protoplasm has apparently no power of assimilating inorganic matter.

The Fungi and parasites live on organic matter; and this is probably the case to a great extent with cultivated plants grown with excess of organic manures. This will be referred to hereafter.

One degree less general are the laws regulating the *forms* of the cellular sacs or *cells*. These determine at the same time the specific form of the plant in the Unicellular Algæ.

Next follow the laws of development of the *secondary deposits* upon the walls of the cells, which are valid throughout the whole Vegetable Kingdom, but more and more complex in the successively higher classes.

The laws of combination of the cells into *tissues* are a little less general, the diversity increasing here again in proportion to the higher position of the species.

The laws regulating the *forms of organs* are of very great importance and interest; and in these we have to distinguish two aspects, or, it may be said, two coexistent series.

The principal Classes of Plants are characterized by respectively possessing a peculiar type or plan of combination of the organs, having not only a morphological but a physiological speciality. The type, more or less recognizable, is a mark of the existence of a common law of inherited organization throughout each class. Within the limits of the Classes exist almost infinite varieties of form, referable to morphological laws which have been investigated in the First Part of this work. A complicated but graduated and interconnected body of laws was there shown to regulate the variations of forms in plants generally.

Lastly, in the description of the *Natural Order* of plants, it will have been recognized that there are still more special laws of development, causing the existence of resemblance in limited groups of species; and, beyond this, every species or kind of plant has its form and mode of life more or less definitely fixed and regulated by its special law of organization derived from hereditary descent, and modified in accordance with external circumstances and the requirements of the plant.

These reflections enable us to explain simply the terms higher and lower classes or species of plants. In the *Protococcus*, consisting of a simple cell, the specific law, that which determines the characteristic form, follows immediately on the first of those above indicated. In a *Conferva*, the second and third are both involved; and the specific law at once succeeds these. Proceeding step by step, we shall find species in which there is a diversity of forms of the cell and of tissues (higher Algæ); next, an additional diversity of organs (leafy Cryptogamia); and then come into play the laws of the physiological and morphological types of combination of organs, which are most complicated in the Flowering Plants, in the development of which, however, from the original germ, or embryonal vesicle, we may trace, in a graduated series, the commencement of the operation of the successively less general laws of organization.

Not only do different plants display great diversities in structure and composition, but each individual plant offers more or less diverse characters at different periods of life.

Plants commence their independent individual life in the form of a cell or a group of cells separated from a parent organism. In the lower plants such cells, once fully developed, as *spores* or as *gonidia*, are capable, under suitable circumstances, of growing up into complete plants. In the higher Classes these cells (*embryonal vesicles*, or the *primary cells of a leaf-bud*) go through the earlier stages of development connected with the parent organism, and are detached (as *seeds* or as *bulbils*, &c.) already provided with rudimentary organs of vegetation.

Duration of Vitality.—In those cases where the detached bodies are products of simple vegetative cell-division, they often proceed at once to grow up into new plants (*gonidia*, *zoospores*), but more frequently their vitality remains latent for a certain definite period (*bulbils*, *spores* of Mosses, Ferns, &c.); and when the body is a result of sexual reproduction, it almost always remains for a more

or less indefinite period (capable of being shortened or prolonged within certain limits by external causes) in a state of rest (*seeds, resting-spores of Algæ*, &c.), and then undergoes peculiar internal changes before recommencing development (*germination*) in order to grow up into a new plant.

Seeds and resting-spores (and to a less extent the resting-organs produced in vegetative propagation, as *bulbs, tubers*, &c.) are organized in a manner especially adapted to preserve the latent vitality from injury by external influences. They can withstand great variations of heat or cold, especially in the absence of moisture. Most seeds will bear a temperature very far below freezing-point if kept dry. Wheat left in the Arctic Regions by the crew of the 'Polaris,' and brought home by Sir George Nares, after two years, was found to have its germinating power unimpaired, and many will even bear an exposure to 100° or 110° Fahr. in dry sand. Prolonged immersion in water at 120° kills most seeds, unless the skin is very thick and they contain oil instead of starch in the endosperm. Some seeds will bear a short immersion in boiling water (*Veronica*); but the seeds of Cereals, Beans, Linseed, and other plants scarcely survive a 15 minutes' soaking in water of 110°, while they will bear 140° in steam and 170° in dry air.

Some seeds naturally lose their vitality very soon: this is the case with the seeds of *Coffea, Magnolia*, &c.; while other instances are related in which it has been preserved for centuries. The cases related of the germination of Wheat taken from Egyptian Mummies are fallacious: but well-authenticated instances exist of long preservation.

The resting-spores of Confervoids (*Protococcus*) have been revived after remaining for years in herbaria; and it is in curious relation to their growth in shallow pools, often dry in summer, that the resting-spores of these plants appear to require to be dried before they will germinate. Mr. Munby found a bulb of a species of *Narcissus* sprouting in his herbarium after it had been gathered (in Algeria) upwards of twenty-two years. This bulb, removed into the greenhouse and potted, produced flowers.

Periodicity of Growth.—Plants are subject to a periodicity in their vital phenomena, partly dependent on their own laws of growth, partly on the seasons in the climate where they grow. As dependent on special laws may be noted the differences between annual, biennial, and perennial plants (properly so called), between deciduous-leaved and evergreen trees, &c.

Annual plants are such as germinate from seed, produce their whole vegetable structure, flowers, fruit, and seed, and die away in one season, between spring and autumn: such are the summer annuals of our gardens. *Biennials* sprout from seed in one season, and bloom, bear fruit and seed, and die in the second; the Turnip, Carrot, *Œnothera biennis*, &c. are examples of this. *Perennial plants* exhibit several varieties of condition. *Herbaceous perennials* (like the Daisy, Primrose, Garden Flag, &c.) germinate in one season, and produce a subterraneous rhizome, of indefinite

duration, which annually sends up a flowering shoot or shoots. Other perennial plants of this kind form one shoot, which vegetates uninterruptedly for many years before it flowers (*Agave americana*, Talipot Palm, &c.); and after ripening its seeds the stem dies down, leaving usually a number of offsets from the axils of its leaves (*monocarpic perennials*).

Woody perennials, trees and shrubs, usually vegetate for several years before flowering, but are subject to periodic rest, throwing off their foliage and renewing it upon fresh shoots of the same stem every season; and when they flower, the operation exhausts their accumulated powers of development so little that they continue to flower periodically (every season if in favourable condition) throughout life.

Habit of Plants.—The "habit" assumed by plants depends in some degree on external conditions. Thus many of our garden annuals are perennial in their native climates: for example, *Ricinus* (the Castor-oil plant), *Mirabilis*, and other genera are annual herbs with us, but perennial and even woody in warmer climates. And some annuals may be made to vegetate for more than one season by removing the flower-buds as they appear, as in the case of the so-called Tree-mignonnette. The Winter-corn of agriculturalists is really an annual plant, sown in autumn to obtain stronger growth, and is not specifically different from Spring-corn, sown in spring and reaped in autumn. The common Cherry-tree retains its leaves during the whole year and becomes an evergreen in Ceylon; and many similar instances of changed habit, the result of altered condition, might be cited, while for further particulars respecting the duration of plants the student may refer to the sections treating of the Morphology of Stems.

Few perennial plants retain their appendicular organs beyond certain definite periods. Ordinary deciduous trees lose their leaves in autumn in our climate; and previously to their fall their organs undergo internal changes, in which the assimilated matters are, for the most part, removed and their green colour altered. They are generally cast off by a regular fracture where they join the stem (p. 540); in the Oak, Beech, and other trees they die in autumn, but do not fall away at once, often remaining, when not exposed to violent winds, until pushed off by the expansion of the stem in the next spring. Evergreen trees and shrubs retain their leaves green and living until the succeeding season, when the new leaf-buds expand, as in the Cherry-laurel, *Aucuba*, &c.; or, as in many Coniferæ, they remain attached to the stem for several years (*Araucaria imbricata*, *Thuja*, &c.). In some of these cases the so-called leaves are probably foliaceous branches. The leaves of arborescent Monocotyledons (Palms) are also of long duration. The parts of flowers and ripe fruits are likewise cast off in most cases, although the fruits from which seeds have escaped sometimes remain long attached in a dead condition (Conifers).

The axis is the only permanent part of the plant; and the unlimited duration of this is strictly dependent on the development of leaf-buds. When a shoot ends in a blossom-bud, the growth of that branch of the axis is arrested, and the prolongation of life depends either on the axillary leaf-buds situated below or on the formation of an *adventitious* bud.

The production of flowers and fruit is an exhausting process; it has

just been noticed that annuals may be made to live several years by preventing them from flowering. The arrest of growth of the large and highly developed axes of monocarpic perennials (*Agave*, Talipot Palm, &c.) is a necessary consequence of the terminal bud producing blossom instead of leaves; but the formation of propagative offsets from the leaf-axils before death is strictly dependent on the degree of vigour possessed by the main axis at the time of flowering.

The duration of herbaceous perennials may be regarded as unlimited, since they are always placed in a position to form new absorbing organs (roots) in the vicinity of their buds. The duration of trees is also theoretically unlimited; and in many cases great age is attained; but ordinarily trees acquire increased vigour with age up to a certain point, and then begin to decline, a circumstance attributable to the increasing distance to which the buds are removed from the roots, the obstruction to the flow of sap, the local decay of the roots and trunk from external injuries, &c. Cuttings from old trees, if taken from sound shoots, may be made the foundation of new trees as vigorous as the parents were in their earlier years.

Palm-trees grow to an age of 200 years or more; the *Dracænæ* (Dragon-trees) of Teneriffe have been known as old trees for centuries. Oaks, Limes, Cedars, Yews, &c. are known to have lived many centuries; and other cases are on record of gigantic trees whose age, deduced from the number of rings of growth of the stems, would amount to upwards of 3000 years. The *Bertholletiæ* of Brazil, the *Adansoniæ* of Senegal, and the *Wellingtonia* or *Sequoia gigantea* of California (363 feet high and 31 feet in diameter at the base) are examples of this.

Death of the Plant.—In herbaceous perennials the older parts of the plant die and decay in a limited period after the development of the new axes. In Dicotyledonous trees also the older part, which is enclosed by the new layers, and becomes consolidated into heart-wood, must be regarded as dead after a certain period, ceasing even to carry sap mechanically: and we see hollow trees of this Class living and growing, where the whole of the older part has been lost by decay, a living shell of wood constituting the bond of connexion between the roots and the growing branches of the axis.

This death of the older tissue is not so common in arborescent Monocotyledons; but it is observed in *Pandanus* (fig. 10), where the base of the stem and the old roots decay, new (adventitious) roots sprouting out from the living part of the trunk in a continual advance upwards.

The death of a plant or part of a plant depends upon the death of the cells composing its tissues. The duration of the life of individual cells is very different, according to their position and function. Cells situated at growing-points (in buds, cambium-regions, tips of roots, &c.) are very transitory, since during active vegetation they are continually divided, as parent cells, into two or more new cells, part of which are left behind as *permanent cells*,—those situated at the periphery, or most advanced point,

becoming in turn the *parent cells* of a new generation. The permanent cells become parts of parenchymatous, prosenchymatous, or vascular tissues in the vegetative organs, or parts of reproductive structures in flowers and fruits. Thus they run through a course of life dependent in each case on the laws of development of the plant, according to which its organs have a shorter or longer duration. The *death* of the organ or tissue in which they exist results from the cessation of the vital activity of the cells according to these laws; and their *decay*, from the now unopposed operation of simple chemical forces.

Vital Phenomena.—The principal vital phenomena exhibited by plants are connected either with the maintenance and increase of the individual organism, or with the production of special structures endowed with the power of growing up into new individuals when thrown off by the parent.

We say the *principal* vital phenomena, because there are some which we cannot strictly affirm to belong to either of the above classes, although there can be but little doubt that they are in some way related; of these are the movements of plants like the Sensitive-plants, the folding up of leaves or flowers, &c.

Vegetation, Nutrition.—The processes of *vegetation*, or growth of the individual, are, from the peculiar organization of vegetables, connected with the processes of *reproduction*, properly so called, by the phenomenon of *multiplication* or *propagation* through natural or artificial separation of portions of the structure which might remain and form branches of the parent stock. This *vegetative propagation*, distinct in important anatomical and physiological characters from *sexual reproduction*, is found in all classes of plants, and from its importance in relation to cultivation deserves separate consideration.

The construction of plants from a number of like parts more or less physiologically independent allows of their being increased by mechanical subdivision of the parent "stock," which is effected by making *cuttings*, &c. The same occurs in the propagation of plants by bulbs, tubers, &c.

The Vegetative processes of plants are divisible into several heads, which, however, present many points of interconnexion.

Nutrition, properly so called, can only be said to go on in the protoplasmic matters found in the interior of cells, since it is these substances alone that exhibit phenomena of consumption and reparation. The tissues of plants are, under ordinary circumstances, never renewed; the only changes which they undergo are stages of progressive development or growth, succeeded sooner or later by decomposition.

Development or *organization* constitutes the most striking manifestation of the vegetative action; but this is a final result, prepared from, and incessantly accompanied by, phenomena which are

results chiefly of the regulated action of physical and chemical forces.

The subsidiary operations of vegetation are—*absorption* of food, *diffusion* or *transmission* of fluid through the organic structure, *assimilation* of absorbed material, and, intimately connected with this, the processes of *respiration*, *transpiration*, and *metastasis*. *Secretion* is more nearly related to *development* than to the processes just enumerated. The relations of many of the secretions of plants are very obscure. Starch, chlorophyll, fixed oils, sugar, &c. are of course intimately connected with the vegetative growth; but we have little clue to the importance, as regards the plant, of the essential oils, resins, alkaloids, &c.

The *Vegetative Propagation* of plants presents special modifications connected with the peculiar conditions of organization in the different Classes; and there are some important considerations connected with the contrasts existing between the results of this and of sexual reproduction.

The *Sexual Reproduction* of plants offers a series of phenomena of much interest when viewed comparatively throughout the different great Classes; and the phenomena of *Hybridization* and the influence of sexual reproduction in the maintenance of specific characters require especial notice from the vegetable physiologist.

As the Vegetative propagation is a process of vegetative life trenching on the region of reproduction, so many of the phenomena accompanying sexual reproduction are properly special vegetative actions induced by peculiar stimuli: among these are the phenomena of ripening of fruits and sporanges, the evolution of heat from flowers, the irritable movements of floral organs, &c. These, and some other unclassed phenomena, will be most conveniently examined apart. In the succeeding Chapters on Physiology we shall examine separately:—1, the processes of Vegetation; 2, the phenomena of vegetative Propagation; 3, the physiology of sexual Reproduction; and, 4, various unclassed phenomena met with in a more or less limited range of cases of vegetable life.

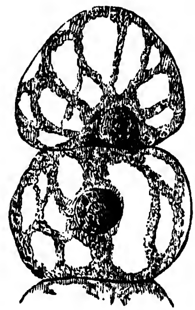
Sect. 2. Cell-Life.

Movements of the Protoplasm, &c.—Intimately connected with the early history of the protoplasm of the cell (p. 495) are certain physiological phenomena of the contents of individual cells, which will be most conveniently described here.

During the time when the protoplasmic contents of young cells are becoming gradually hollowed out into spaces filled with watery cell-sap (p. 494), a regular movement of this protoplasm takes place, which may be observed very readily in young hairs of Phanerogamic plants (fig. 586), and which probably takes place in an

early stage in all other structures. This movement, which is erroneously called *rotation* of the *cell-sap*, is a circulatory movement of the protoplasm made perceptible by the minute opaque granules which exist in the colourless fluid. The nucleus is also carried slowly along in this movement, which, when the protoplasm has become converted into a mere network of cords, has the appearance of a system of reticular currents (fig. 586). This movement of the protoplasm ceases in most cells before they are full-grown; but in many aquatic plants, even of the class Phanerogamia, the protoplasm does not become excavated in the same way as it does in the cells of *hairs* &c., but applies itself as a thickish layer upon the inside of the cell-walls, and, retaining its activity, performs a rotatory movement around the wall of the cell permanently. In *Chara* the moving layer of protoplasm is not applied upon the cell-wall: the primordial utricle, with the chlorophyll-corpuscles imbedded in it, lies on the cell-wall motionless; and a thick mucilaginous layer, situated between this and the central cavity filled with watery cell-sap, continually circulates.

Fig. 586.



Two cells of a hair of the stamen of *Tradescantia*, with nuclei and reticulated currents of protoplasm. Magn. 250 diam.

The circulation in reticulated currents is most easily observed in young hairs of the higher plants. The movement of the parietal layer of protoplasm is made very visible in the leaves of *Vallisneria* by the green chlorophyll-corpuscules imbedded in it; and it may be well seen in *Anacharis*, in the delicate tissues of *Hydrocharis*, *Stratiotes*, &c. It occurs in the rootlets and other parts, as well as in the leaves. The phenomenon is most strikingly shown in the Characeæ, especially in the *Nitellæ*, which are simpler and hence more transparent forms.

This movement is only affected by substances that injure the healthy condition of the structure, such as chemical agents producing bursting or solution of the tissue, heat sufficient to cause coagulation or solution of contents, &c. In *Chara*, the large cells may be tied across, and yet the circulation be set up again in each of the chambers thus formed. Electrical currents do not affect it.

Causes of the Movements; Action of Light.—The movements in the protoplasm are attributed to various causes according to the nature of the movement, such as contraction of certain portions of it, varying degrees of imbibition in different portions of the mass, the alternations in this wise giving rise to the currents. The movements connected with cell-division and growth and the rotation of the protoplasm take place in darkness as well as in the light. In many cases it has been definitely proved

that the movement of the juices in which chlorophyll-granules are contained is directly dependent on the agency of light, especially of the more highly refrangible rays of the spectrum. Under the influence of diffused light the chlorophyll-granules range themselves parallel to the surface. At night, as well as under the influence of direct light and of the most luminous and least refrangible rays, they are disposed at right angles to the surface, on the lateral walls of the cells. If, however, the light fall from one side only, and the illumination be prolonged, the grains show a tendency to accumulate on the side of the cell most brightly illuminated, just as the zoospores of Algæ do. Under unfavourable external conditions (low temperature, age, or deficient light) the chlorophyll grains are arranged against the sides of cells adjacent to others, and not on the free surface as under normal circumstances.

Analogous to the *rotation of the protoplasm* are the movements of the *ciliated zoospores* of the Algæ and of the *ciliated spermatozoids* or *antherozoids* of the higher Cryptogamia and the Algæ.

Zoospores are formed by the contents of vegetative cells becoming isolated from the cell-wall, and individualized into one (*Œdogonium* fig. 505), a few (*Ulva*, *Ulothrix*, &c.), or numerous (*Cladophora*, fig. 512, C, and Phæosporeæ) corpuscules, which break out from the parent sac, and when free are seen to be provided with vibratile cilia (2, 4, or many), and to swim about actively for a period of from half an hour to several hours, then to settle down, become encysted by a cellulose membrane, reassume the characters of ordinary vegetative cells, and grow up into new plants by cell-division. It has been observed that those zoospores with cilia at one end direct that extremity (which is destitute of chlorophyll) towards the light; and, moreover, the locomotion of these bodies is accompanied by a movement of rotation on their own axis.

Spermatozoids are filiform bodies of various forms, mostly presenting one or more spiral curves, or minute globules, and usually furnished with vibratile cilia. They are formed by a metamorphosis of the protoplasmic matter of cells developed for the purpose in the antheridia of the Cryptogamia. They are extremely minute, but move very actively when they escape from their parent cells, continuing to swim about for some time, being destined to find their way to the archegonium (or to the spores in Algæ), to perform the fertilization of the germ-cell. Many, however, never reach this, and they gradually dissolve away.

In the Volvocineæ (fig. 503, D) the separate primordial utricles lie imbedded in a common envelope, without a membranous cell-coat, retaining their vibratile cilia throughout life, only becoming encysted and formed into proper vegetable cells when converted into resting-spores. In the intimate affinity between these productions and the Protozoa, or lower Infusorial Animalcules, we perceive the close bond which exists

between animal and vegetable organization when reduced to its lowest terms.

As long as a cell retains its active protoplasm, it is capable of producing new cells and organized forms of assimilated matter, like starch and chlorophyll, in its contents. This is the case, of course, in all nascent tissues; but it ceases to be so at various periods in different parts of the vegetable organization. In all woody tissues, in all pitted and spiral-fibrous cells, it disappears early, secondary deposits of the ligneous character being formed apparently from the watery cell-sap. In herbaceous organs, such as leaves, in the cells of the Cellular plants generally, in fact in all the properly living structures, the protoplasm remains.

This explains why the power to form adventitious buds exists not only in the cambium-layer of the higher plants, but, under certain conditions, even in the leaves (as in *Bryophyllum*, *Gloxinia*, &c.), and why *gemmation* or propagation by little cellular bulbils, or isolated cells detached from the vegetative organs, is so common among the Cellular plants, and in the Mosses and Liverworts, where parenchymatous tissues so greatly predominate.

Nutrition in Cellular Plants.

The elementary structures being essentially alike throughout the Vegetable Kingdom, and the physiological phenomena of vegetation depending almost entirely upon processes taking place in the individual cells, it is very instructive to examine the phenomena of nutrition and growth in those simply organized plants in which we are able to observe directly the changes in the living cells.

Many cellular aquatic plants are especially adapted for these researches, from their simple structure, transparency, and their aquatic habit, which permit us to keep them in a growing condition in glass cells beneath the microscope. By way of illustration the history of the Yeast-plant is subjoined.

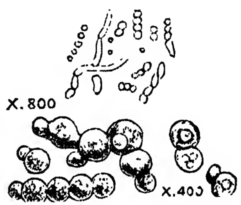
The Yeast-plant.—What is called the "Yeast-plant" consists of a particular form of the *mycelium* of a Fungus (fig. 587, *Torula cerevisiæ*). It is composed of simple cells, which will go on multiplying by budding for an indefinite time if placed in a liquid containing a mixture of saccharine or dextrinous substances, together with albuminous matters, at a moderately warm temperature (59°–67° F.), bubbles of carbonic dioxide being given off. These cells are simple membranous vesicles, with their walls formed of a modification of the compound (*cellulose*) of which all vegetable cell-membranes are formed, and mixed with which are very minute quantities of sulphur, phosphorus, potassium, magnesium, and calcium. Within the cells exist nitrogenous matter in the condition of protoplasm, fatty matter, and water. The increase of the plant is dependent on the assimilation of substance requisite for the production of new cell-membranes, and of other substances to furnish new

nitrogenous contents. When no material for forming cellulose exists, the plant cannot grow; but in solution of pure sugar in the absence of any nitrogenous substance, the plant will multiply its cells for a certain time, the protoplasm of the old cells being transferred into the new ones as they are successively evolved. But under these latter circumstances the cells become gradually smaller, and at length cease to multiply, a portion of the nitrogenous matter being *wasted* in the reproduction until it becomes insufficient to carry on the growth.

On the other hand, if sufficient nitrogenous matter exists, the fermentation goes on, accompanied by the production of a more developed form of the *mycelium*, consisting of elongated interwoven filaments (the so-called *Vinegar-plant*); and development of this continues, if not interfered with, until the liquid consists of little else but pure water. The final form is the so-called "mother" of vinegar, which destroys the acetic acid.

There is another mode in which the Yeast-plant is multiplied, and that is by endogenous segmentation of the cells. The protoplasm divides by segmentation (fig. 593) into four subdivisions, around each of which a new cell-wall is secreted, as subsequently explained, p. 585. This mode of multiplication may be seen by placing a little yeast on a thin layer of plaster of Paris beneath a bell-glass so as to ensure sufficient moisture. After a week or more the new cells may be seen with a $\frac{1}{8}$ object-glass.

Fig. 587.



The Yeast-plant (*Torula*); large form seen at the bottom of the liquid and smaller form on the surface of stale beer.

In whichever way the multiplication is effected it is clear that the materials for such increase must be derived from without—the plant must feed; and it has been found, experimentally, that it requires substances to build up and renew its protoplasm or nitrogenous constituent, cellulose, or fatty materials or carbo-hydrates, mineral matters (sulphur, &c.), and water. It is not necessary that these substances should be in the food, simply that the latter should contain the elements out of which they can be formed by the plant. For experimental purposes Pasteur's solution * may be used: this consists of a solution of sugar, furnishing the hydrocarbon, ammonium tartrate supplying the requisite nitrogen, potassium phosphate, calcium phosphate, and magnesium sulphate yielding the requisite mineral ingredients. The breaking-up of these ingredients, and their

* Pasteur's fluid :—

Potassium phosphate	20	parts
Calcium phosphate	2	,,
Magnesium sulphate	2	,,
Ammonium tartrate	100	,,
Cane-sugar	1500	,,
Water.................	8576	
	10,000	

recombination in the plants in the single cell, is a "vital" property, one not possessed by dead matter.

Fermentation.—The succession of phenomena exhibited is connected with a series of chemical changes which are probably somewhat as follows. The whole of the processes are accompanied by evolution of carbonic dioxide. The earlier growth can go on without access of oxygen, as is evident from the fermentation proceeding in large vats with a stratum of carbonic acid several feet thick over the surface of the liquid; the growth in the latter stages takes place most freely with access of air. The original liquid contains grape-sugar (glucose), or dextrine, and nitrogenous matters. If the yeast-cells be kept out from this fluid no fermentation occurs; but if yeast be added the protoplasmic matter of the yeast decomposes a portion of the fluid, forming cell-membranes. The chemical action set up disturbs the combination in the rest of the sugar, which loses carbonic dioxide and becomes alcohol. If the growth of the Fungus continues, the alcohol becomes decomposed (seemingly by *contact-action* again), absorbs oxygen from the atmosphere, and becomes acetic acid.

It is not clear in most cases to what extent the Fungus is nourished on the alcohol, or on the saccharine or dextrinous matters mixed with the alcohol. To form cell-membrane from alcohol would require the absorption of a large quantity of oxygen, and the formation of much acetic acid and water. The growth of the Vinegar-plant in solution of sugar, then, would appear to cause simple liberation of water, while the contact-action in like manner decomposes the sugar into acetic acid. The "mother of vinegar" finally is developed at the expense of acetic acid, with separation of water.

The processes here briefly described *cannot* be disregarded when we inquire into the mode in which plants generally take up their food. Not only do the Fungi all feed in this way—as, for instance, the Dry-rot (*Merulius*), which lives on the dead substance of timber, or the parasites like *Pucciniæ*, the Potato-fungus, &c., which send their mycelium into the tissues of living plants to feed upon their juices—but the same laws evidently regulate the nutrition of the colourless *parasites*, such as Orobanchaceæ (p. 325), and the Balanophorads and allied plants (p. 354).

Following out this train of reasoning, we are irresistibly led to the conclusion that the same processes may occur in all plants under particular circumstances, although not absolutely necessary except at certain stages of growth.

Germination.—In germination, doubtless the decomposition of the store of starch &c., with evolution of carbonic dioxide, during the recommencement of cell-development, is a phenomenon essentially similar to the development of the Yeast-plant. And we cannot find any reason to suppose that the roots of plants can *refuse* to take up organic matters existing in a state of solution in the soil. The extent to which growth may be stimulated, without access of light, by profuse supplies of organic food, is strikingly illustrated by the many succulent vegetables cultivated for the table,

such as Sea-kale, Celery, forced early Rhubarb, &c. And the tissues of the plants thus grown have exactly that weak, succulent character which is so striking in most leafless parasitic plants and Fungi.

Further applications of these facts will be dwelt on in the succeeding Sections.

Assimilation of Inorganic matter.—By far the most striking phenomena of vegetative life are those in which inorganic matters are assimilated, and the gaseous and liquid constituents of the atmosphere and soil supply the requisite food.

If all plants required organic food, the organized substance upon the globe must continually decrease, since, as we have just seen, those which do live upon organic matter *waste* this through decomposition by *contact-action*. But the organic matter of soils, upon which plants grow and decay in successive crops, undergoes continual increase, as we observe in the accumulation of vegetable mould on undisturbed grass plains and in forests where the débris (fallen leaves, underwood, &c.) is not removed.

Food of Plants.—The majority of plants feed upon water, carbonic dioxide, ammonia, nitrates (and perhaps other nitrogenous compounds), with small quantities of various other elements, such as sulphur, phosphorus, and the salts of lime, potash, &c. Such plants can only flourish under the influence of light; and under this influence they produce, from the above materials, new cellulose &c. and protoplasmic matter. The assimilation is in such cases, as a general rule, accompanied by the assumption of a green colour, from the formation of chlorophyll.

Exceptions to the last assertion appear to exist in the red, olive, and other peculiarly coloured Algæ, in which no chlorophyll is produced; but we are ignorant of the processes which go on in the vegetation of these plants.

Nutrition in Algæ.—The history of the changes which take place in the cell-contents of the green Confervoid Algæ (figs. 512, 513), which we are able to observe to a certain extent beneath the microscope, affords some material towards the comprehension of the processes which have their seat in the green parts of the higher plants.

We observe, in the elongating apical or branching cells of the Confervoids, that the contents of the nascent parts (as in the upper half of the dividing-cell of *Œdogonium* &c.) are chiefly composed of colourless protoplasm, with watery cell-sap. Under the influence of light, green chlorophyll-corpuscles become more and more abundant; and, under favourable circumstances of light &c. (accompanied by liberation of oxygen gas), the chlorophyll-corpuscles soon present starch-granules in the interior, which multiply and increase considerably in size. This formation of starch occurs chiefly after the cell has attained its full growth, and may be regarded as a continuation of the process which

produced the cellulose of the cell-wall, now no longer required for the purposes of the individual cell, the contents of which, however, proceed with their assimilative action. After a time the cell prepares for propagation, or reproduction. Then the starch-granules disappear, apparently by solution, into dextrinous or analogous matter requisite for the development of new cell-membrane, which soon takes place, either in cell-division (p. 451), or, if the primordial utricle is discharged from the parent cell in the form of zoospores (p. 451), in the formation of the cell-membranes of these bodies after they have come to rest.

Where resting-spores are to be formed, different changes ensue after the solution of the accumulated starch. The new cell, intended to remain in a quiescent condition, becomes coated by a cellulose membrane, or often two distinct concentric coats; and, at the same time, that portion of the contents consisting of dextrinous or analogous matter which has not been consumed in forming cell-membrane becomes converted into *fixed oil*, the green colour disappears, and the contents assume a red or brown colour, and external stimuli (light, &c.) produce no influence. When these bodies germinate (which usually only occurs after they have been dried up and are again placed in water), the chlorophyll gradually reappears and the oil vanishes, and the entire course is run through again.

Transfer of Stored Nutriment—*Metastasis*.—Comparing these phenomena with what we observe in the higher plants, we notice the similarity as regards the production of chlorophyll in the leaves, followed by the appearance of starch-granules, as a form of *accumulated* nutriment. But the functions being more localized as the organization is more complicated, the starch thus formed is subsequently dissolved, and is carried away to the growing tissues of the plant, to the buds, cambium-region, and roots, where it is laid up in autumn, very often in this same form, but not unfrequently in the condition of fixed oil, as in the rhizomes of *Cyperus*, of *Lastræa Filix-mas*, &c., and, above all, in structures which, like the *resting-spores* above mentioned, are to remain quiescent while exposed to considerable diversity of external conditions, namely in seeds, as in the cotyledons of Cruciferæ, Almonds, Nuts, Walnuts, &c., or in the perisperm of Poppies, Euphorbiaceæ, &c.

The oil (or starch in other cases) stored up in the seeds and rhizomes by *metastasis* undergoes decomposition and solution in germination, to supply material for the cell-membranes of the nascent plant until the roots have become sufficiently developed to provide for it.

We have at present no very satisfactory evidence of the kind here brought forward to indicate the mode in which the nitrogenous matters, necessary for the formation of new protoplasm, are taken up. The question of the assimilation of nitrogenous matters will be considered in the following section, on the Food of Plants.

Sect. 3. Food of Plants.

Constituents of Plants.—The first step in the investigation of this subject is to ascertain what substances enter into the composition of vegetable structures and juices.

Analyses of plants by chemical means, and in some instances by the spectrum, have demonstrated the existence of the following chemical elements in plants:—Oxygen (O), Hydrogen (H), Carbon (C), Nitrogen (N), Chlorine (Cl), Bromine (Br), Iodine (I), Fluorine (F), Sulphur (S), Phosphorus (P), Silicon (Si), Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Aluminium (Al), Manganium (Mn), Iron (Fe), Zinc (Zn), Copper (Cu), Lead (Pb), Titanium (Ti), Arsenic (As), Lithium (Li), Rubidium (Rb), Cæsium (Cæ), Strontium (Sr), and Barium (Ba).

All of these, however, do not exist in every vegetable substance; the first four are universally present, while a perfectly healthy condition cannot be assured unless sulphur, potassium, calcium, magnesium, iron, and phosphorus are also present at some time or other. Some of these substances are dissipated by burning, others remain after burning and constitute the *ash*; such are the earthy alkalies and metallic substances. The proportion of ash ingredients is about 3–6 per cent. of dry matter, *i. e.* matters dried till they cease to lose weight at a temperature of 100° C.

Proportionate Quantities of the Constituents.—These elements are not taken up by plants in a simple form; and none of them exist as such in vegetable substances. The compounds of the different elements differ much in the proportion in which they exist. Water (HO or H_2O) may form 90 to 95 per cent. Of the dry substance, compounds of carbon, hydrogen, and oxygen (C, H, O) may form 66 per cent.; the carbon furnishing about 50 per cent., the oxygen about 33 per cent., the hydrogen about 5 per cent., the nitrogen $\frac{1}{2}$–4 per cent.; the alkalies, earths, and metallic oxides commonly form 1 to 4 per cent., in rare cases as much as 20 per cent.

The great mass of all plants is composed of the first four elements in the list—the solid parts of compounds of carbon, hydrogen, and oxygen; the protoplasmic cell-contents of compounds of these three elements, with the addition of nitrogen. Sulphur and phosphorus appear to be necessary constituents also in the protoplasmic compounds; the alkalies and earths are, in most cases, requisite in the processes of elaboration, but may, in many cases, be substituted for one another, and perhaps in certain cases may be replaced by ammonia. Potash is an indispensable element in plant-growth—its presence being essential in the formation of starch from chlorophyll. Chlorine is necessary in many plants: iodine and bromine are also met with, particularly in marine plants; but it is not clear whether their presence is necessary, or merely an inevitable result of the absorption of sea-water. Iron and manganese are met with very commonly, iron being essential to the formation of chlorophyll, and therefore of the utmost consequence to plant-growth; copper and zinc more rarely; silica abounds in certain Orders (Grasses, Equisetaceæ), and is met with in many plants in smaller proportions. The most necessary ingredients for the due nutrition of the plant are, in various proportions

according to circumstances, a nitrate or an ammonia salt, a salt of potash, soda, lime, magnesia, and iron, while lime is necessary in the formation of the cell-wall. These substances appear to act as ferments: for instance, lime is stated to effect the conversion of cane-sugar into cellulose, and to be influential in the transport of starchy materials in a soluble form.

Sources of Nutriment.—We have stated that (green) plants in general acquire their nitrogenous food by their roots (from the nitrates of the soil), and their carbonaceous food by their leaves. The sources of the food are therefore the soil and atmosphere in which plants grow; and the inquiry presents itself at once as to the form in which the food is supplied to and taken up by plants.

How Plants get their Food.—On the one hand, we know that plants can absorb substances only in a liquid or gaseous form; on the other, we know that both the atmosphere and the soil contain carbonic dioxide, water, and various nitrogenous compounds soluble in the latter. The alkalies, earths, &c. exist only in the soil, and in more or less abundance and in more or less soluble forms in different cases.

Observation teaches us that the simpler plants, such as the Palmelleæ, Lichens, many Mosses, &c., can grow upon bare rocks or stones, and obtain their carbon, hydrogen, oxygen, and nitrogen from the atmosphere alone; and experiment shows that these are supplied in the form of carbonic dioxide, water, and ammonia; the substratum here supplies only the small proportion of mineral substance that is required. Moreover it is possible to grow a plant to maturity, and even to make it ripen its seed, in distilled water containing in solution only the ash-elements of aquatic plants, such as Confervas, &c. Similar growth may be obtained by growing a plant in a watery solution of the necessary mineral ingredients of the plants, together with a nitrate or an ammonia salt, the excess of carbon in these cases being derived from the air. Numerous and important results have been obtained by growing plants in experimental solutions of this kind—*water culture*; and by their aid, as well as by field trials, it has become possible to compound *artificial manures* adapted to the requirements of particular plants.

Further, it is observed that, if a vegetation of this kind goes on undisturbed for a lengthened period, the decay of successive generations of plants leads to the accumulation of organic substance, in vegetable mould, the material of which has been derived from the atmosphere by the plants, but has not been *consumed*, *i. e.* decomposed into its original forms of carbonic dioxide &c., by them and their successors.

From these facts it has been concluded, in the first place, and

truly, that green plants have the power of feeding upon inorganic substances, and fixing them in definite organic compounds: secondly, but with less justice, that this is the universal law of vegetable nutrition—that plants live exclusively on inorganic substances, which they convert into organic matters unfit for their own use, and only assimilable after a new decomposition. In regard to certain plants this last assertion is altogether inadmissible, namely the Fungi, the so-called insectivorous plants such as *Drosera*, &c. (in which animal substances are dissolved, absorbed, and appropriated by the action of a ferment), and, above all, the colourless parasites; and not only is it contradicted by the phenomena of their life, but it is opposed to the universal experience derived from observation of the cultivation of plants. Lastly, we know of no cause why plants should *refuse* to absorb organic substances presented to them in a state of solution favourable to endosmotic action in the roots.

It is very true that many even of the higher plants will grow upon soil almost destitute of organic matters, as we see on sandy heaths &c.; but the kind of vegetation which characterizes such soils is very different from that which clothes land covered with vegetable mould. And the influence of manures in agriculture must be attributed in a great measure to the extensive aid afforded to the plant in the shape of additional supplies of organic matters, which bear a kind of compound interest, since the increased growth they produce gives increased power of independent assimilative action.

Spontaneous vegetation is nourished principally by carbonic dioxide and ammonia always existing in sufficient proportions in the atmosphere. The former substance is taken up by the leaves, and the latter is also absorbed by the aerial organs of plants; but the principal supply to the higher plants seems to be furnished through the soil, which receives ammonia dissolved in rain and dew, and, where porous, absorbs it greedily. Soil, and especially the carbonaceous portions, has also the power of absorbing ammonia from the atmosphere.

Plants growing upon soil abounding in decaying vegetable and animal matters are doubtless supplied with part of their food from these sources. Ammonia is a constant product of decomposition of animal substance, carbonic dioxide of this and vegetable matter. But from the researches of Mulder it would appear probable that the old vegetable matters may pass into the living plants without undergoing decomposition into carbonic dioxide and water. The black decaying matter of vegetable origin, called ***humus***, is decomposed in the soil into a series of organic acids, of which the last members possess much affinity for ammonia, and form both with it and the alkalies soluble salts, which may be absorbed as

such by the roots. In favour of such a view is the fact that carbonate of ammonia, or ammonic carbonate (decomposable by crenic and apocrenic acids), appears in many cases hurtful when applied directly to the roots of plants. In addition to the tendency of these organic acids to attract ammonia, they seem to be capable even of causing its production in the soil, since in the progressive oxidation of humus taking place at the expense of water (H_2O), the hydrogen of the latter possibly combines in its nascent state with the nitrogen of the atmosphere to form ammonia.

It has been common in recent works to find the value of humous or carbonaceous matters in the soil estimated very low; they have been regarded either as merely improving the (physically) absorbent power of soil, or as sources of carbonic dioxide, already sufficiently provided by the atmosphere. But the above observations, borne out by the experiments in Turnip-growing by Lawes and Gilbert, are in favour of a higher estimate of the value of decaying carbonaceous matters, and of regarding them as important constituents of farmyard manures for certain purposes. Lawes and Gilbert found that stimulating nitrogenous manures in excess were rather detrimental to the growth of turnips, leaf-formation going on at the expense of the roots; but this was counteracted in a great measure by supplying, with the nitrogenous manures, carbonaceous substances in considerable proportion. Corenwinder, however, states that the roots exhale carbonic dioxide and do not absorb it except in very minute quantities.

Sources of Nitrogen.—It was once supposed that there was a power in living plants to fix free nitrogen from atmospheric air; but this is conclusively negatived by the experiments of Boussingault, Lawes and Gilbert, Pugh, and others. That ammonia is not absolutely necessary for the food of plants is indicated by the effect of nitrates as manures, rivalling that of salts of ammonia. Moreover it has been stated that *ozone* (a peculiar condition of oxygen) converts ammonia into nitrous acid; and there is reason to suppose that the ozone condition of oxygen is produced in certain cases in the liberation of that element by plants. Schlösing states that the ammonia supplied to the soil becomes (if light be excluded) converted in the soil into nitrates by the agency of a vegetable organism acting as a ferment.

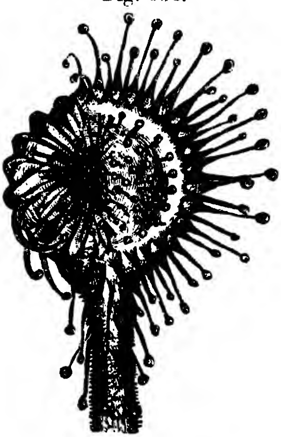
The amount of nitrogen supplied to the soil by rain is insufficient to account for the amount found in plants; but this quantity is supplemented by the direct absorption of ammonia by the leaves, as well as from the soil. Dehérain supposes that decaying vegetable matter has the power of producing ammonia from the free nitrogen of the air; but his experiments have not been confirmed. Schlösing confirms the experiments of Sachs and Meyer as to the absorption by the leaves, and also by the soil, of gaseous ammonia, and corroborates the statements that the free nitrogen of the air is not available for plants except to the

small extent in which, by thunder-storms and electrical disturbances, it is converted into nitrous acid, which latter becoming oxidized, becomes carried down to the soil as ammonic nitrate.

A large proportion of nitrate is lost by drainage, and ultimately finds its way into the sea, where it serves to nourish the marine plants, which in their turn feed the animals. These latter, in decaying, yield ammonia, the excess of which is volatilized into the air, which is thus continually supplied with ammonia, and diffused over the surface of the globe. According to Schlösing, the ocean is the great source of combined nitrogen, ammonia forming the means by which it is conveyed to every part of the globe, supplying the requirements of the vegetable world. Berthelot considers that the nitrogen may be acquired from the atmosphere by electric action.

Carnivorous Plants.—One occasional source of nitrogen remains to be spoken of, for though, according to our present knowledge, exceptional, it seems probable that it is more general than it is at present proved to be. For many years it had been known that some plants, such as Pitcher-plants (*Nepenthes*), Sun-dew (*Drosera*), Venus Fly-trap (*Dionæa*), acted as fly-traps, retaining insects which alighted on them, but it was hardly supposed that these insects contributed to the nutrition of the plant. The experiments of Hooker, Darwin, Tait, Vines, and others have, however, conclusively shown that insects and various animal matters are:—1, retained by viscid exudation, or, as in *Drosera* and *Dionæa*, by movements of the leaf-lobes analogous to acts of prehension in animals; 2, dissolved; 3, absorbed; and 4, appropriated to the requirements of the plant. The shape of the Pitcher-plants (*Nepenthes*, *Sarracenia*, &c.) is evidently adapted to retain insects which may be attracted on or fall into them by accident; and their conformation is such as to prevent their exit, while their intimate structure is such as to facilitate dissolution and absorption. The lobes of the leaf of *Drosera* &c. are endued with sensitiveness, so that when an insect, or a piece of meat or albumen, and, still more, a fragment of ammonia salt, comes in contact with the leaf, the lobes in question instantly begin to fold over and imprison the intruding substance (fig. 588), which gradually disappears, some or the whole of it being absorbed—a process attended by retraction of the protoplasm from the walls of the cell in the shape of a ball (see fig. 590). It was further shown by Riess and Wills that the solution of these nitrogenous matters is dependent on the presence of a substance which acts like a ferment, and in the absence of which digestion does not take place. Gorup, Besanez, and Vines have shown that this ferment closely resembles that

Fig. 588.



Leaf of *Drosera*, showing the glandular hairs on one half infolded over an insect.

of the peptic glands of animals, and is only efficient when associated with an acid; so that the solution of nitrogenous matters by the leaves, pitchers, and other organs of certain plants is now shown to be a true digestive process, resembling in every particular the corresponding process in the intestinal canal of animals.

Ammonia salts have also been found to be rapidly absorbed, and to excite the sensitiveness of the plants to an extraordinary extent: still the actual benefit to the plant seemed doubtful; for to ordinary observation these so-called carnivorous plants appear to thrive quite as well without

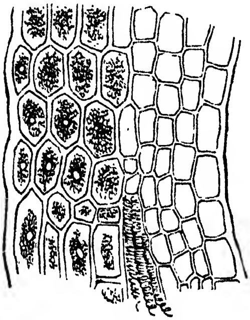


Fig. 590.

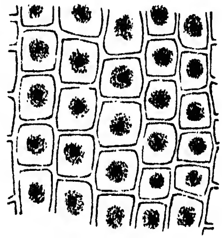


Fig. 589. Cells of petal of *Helleborus* prior to application of meat.
Fig. 590. Cells of petals of *Helleborus* after the application of meat.

as with nitrogenous diet. To settle this point, Mr. Francis Darwin experimented on a large number of plants of *Drosera* grown under like conditions, half of them fed, the other not receiving artificial supplies. The general result, given in the following Table, shows the great benefit derived by the fed plants, especially in the formation of seeds:—

Results of Experiments on Drosera.

	Unfed.	Fed.
Total weight of plants, excluding flower-stems....	100	122
Total number of flower-stems	100	165
Sum of heights of flower-stems	100	160
Total weight of flower-stems	100	232
Total number of capsules	100	194
Average number of seeds per capsule............	100	123
Total weight of seeds	100	242
Total number of seeds	100	380

Sources of Mineral Food.—For their mineral food, plants are of course chiefly dependent on the soil in which they grow. The gradual decomposition of rocks furnishes the earthy and alkaline constituents, which must vary on different formations or according to diluvial actions. Marine plants naturally accumulate many of

the mineral elements of sea-water: and plants growing near the sea derive a certain amount of the salts of sea-water from the atmosphere, brought by the winds; the salt spray is shown to be carried great distances by its being injurious and destructive to many kinds of plants growing exposed to sea-winds.

Sect. 4. Absoi

Since the lower plants consist of closed cells, in the interior of which their vitalized substance resides, and the membrane of their cells, so far as our investigations can reach, is, in general, destitute of orifices, the food of these plants can only be taken up in a liquid or gaseous condition by the still mysterious process of imbibition.

In plants of more complex organization, although loose parenchymatous tissues exist, and the interspaces become concerned in at least *secretion*, the external surface of the plant, by which food must penetrate, is carefully guarded by a continuous epidermis, entirely devoid of orifices in the roots, the principal absorbing organs; and though perforated by stomatal orifices in the leaves and other aërial organs, these are carefully guarded by special contrivances to prevent the entrance of solid matter, and in all cases lead merely to *intercellular* passages, external to the membranes of the vegetable cells.

Absorption in Cellular Plants.—In the Fungi and Algæ absorption appears to take place freely at all points of the thallus to which gases and liquids have access. The structure of Mosses, Hepaticæ, and the smaller members of the higher groups of Cryptogams are likewise so simply cellular that they appear to be little dependent on root-structures.

Absorption in Vascular Plants.—In the higher Cryptogamia and the Phanerogamia the absorption of liquids appears to be confined to the roots and the root-hairs, the epidermis of the leaves &c. being in general so organized as to oppose the entrance of water, while the stomatal cells which guard its orifices, swelling up so as to close the slit between them when filled with fluid, concur to prevent the absorption of water or other liquid. Gases, however, penetrate freely through most cell-membranes, and hence may be absorbed by leaves, and can pass freely through the stomata into the intercellular passages.

Osmosis.—The physical phenomena of *diffusion* and *osmose* are the most important agents in the acquisition, by the cell-contents, of material from without. These phenomena depend, first, on adhesion of the liquid to the solid, and then on any circumstances which cause movements in the molecules of the liquid, such as the attraction one for the other of two fluids of different natures and densities.

We may say, in general terms, that when two liquids of different densities (the one "*colloidal*," or little diffusible, the other "*crystalloid*," or

greatly diffusible) are separated by a membrane or other porous substance, the denser liquid becomes increased in bulk by the passage of the thinner liquid into it through the membrane. This rule is indeed subject to modifications, dependent upon other qualities besides density of the liquids, such as their molecular relations to the substance of the separating membrane, the molecular nature of the membrane itself, &c., since, of two different liquids, that which is more readily imbibed by the membrane passes through in a preponderating current.

When we place simple vegetable cells with flexible cell-membranes, such as many pollen-grains, yeast-globules, &c., in water, their dense cell-contents absorb water and the cell-wall expands, sometimes even bursts. On the other hand, placed in strong solutions of sugar or gum, such cells will lose part of their contents and shrink. But these simple experiments are not sufficient to indicate what takes place in the cells of tissues filled with living protoplasmic matters; for very frequently, when we place such cells in liquids differing in density from their contents, there ensue successive changes of condition, which must also be involved in many natural processes. Thus if we place in water a fragment of cellular tissue from the region where pollen-grains are being developed in the anther, or spores in sporanges, water is absorbed through the cellulose coat, but the primordial utricle contracts; but when the water penetrates the latter, it swells again and sometimes expands beyond its original volume, bursting the cell-membrane when this is weak.

The presence of a membranous or porous septum is not essential to such a process of filtration and admixture as above described. Two liquids of different densities placed in contact will gradually mix by the attractive force that the one exerts on the other. This *liquid diffusion* depends materially in amount on the nature of the liquids—colloid or crystalloid, as the case may be.

Selecting power.—The recognition of *endosmose* as the cause of the absorption of liquids by the young roots and root-hairs affords some explanation of the apparently contradictory phenomena which have been described by those who have experimented with a view to ascertain whether plants have any *selecting power*. It has been shown that there exist some very complex circumstances of purely physical nature in endosmotic processes, and that simple density of liquids is by no means the only important point—alkaline, acid, or neutral conditions of mineral salts causing special peculiarities, dependent on chemical and molecular relations to the membrane or porous interposed substance, and in other cases on chemical actions taking place on one or the other side of the membrane. One of the most interesting and suggestive experiments bearing on this subject is that of Knop, who shows that the more chlorine absorbed by a plant the less lime is taken up.

Some writers assert that the roots of plants absorb all substances indifferently; and the experiments of Vogel and others appear to bear this out. But, not to mention that the ashes of different plants grown in the same soil have different composition, Trinchinetti has shown that different

salts are absorbed in different proportions from mixed solutions; and in De Saussure's experiments living roots absorbed differently from diseased or dead ones. Similar inferences may be drawn from the effects of manures: thus Cereals are specially benefited by nitrogenous manures, Leguminous plants by mineral manures; and yet the ash-analysis of the former shows that they contain a less percentage of nitrogenous matters than do the Leguminosæ. Wheat crops and grasses generally, according to the experiments of Lawes and Gilbert, supply themselves with difficulty with nitrogen, while Clover and other Leguminosæ take it up freely.

Such phenomena as these, however, may be explicable on purely physical principles. It has been proved that different chemical salts exhibit unlike quantitative phenomena in passing through dead endosmotic substances; and thus even from mixed fluids one salt might pass more readily into a cell than another; and, still more, the immediate decomposition of one salt alone, *inside* the membrane, while the other was not affected, which might take place in a living cell, would greatly affect the endosmose, since the cell-contents would soon be saturated with the latter, while the other would not accumulate. According to Knop, the roots will absorb from solutions of nutritive salts an amount proportionate to the degree of concentration of the solution: thus the stronger the solution the more dilute the liquid absorbed by the root; on the other hand, if the solution be less concentrated, the root will take up a relatively larger quantity of water than of the salt. In regard to De Saussure's experiments (which are borne out by what we see beneath the microscope when we apply reagents, such as iodine, to healthy or decaying tissues), there is no necessity to have recourse to a vital agency of selection, since the chemical activity of the cell-contents, quite different in a living and in a dead organism, might account for all the diversities, even if the difference could not be explained by a physical difference of *tension* in the living cell-membrane and that of a dead organ, in which a process of decay immediately commences if it is exposed to the action of water.

It has recently been shown that porous vessels placed in mixed solutions select, just as plants do under similar circumstances; and those solutions which pass most freely through the walls of cells are those which always pass most freely through the sides of the porous vessels. Those cases in which the same amount of any given substance is capable of being absorbed by plants which have nevertheless different chemical composition, may also be explained by the different osmotic powers possessed by the cells of different plants. Thus, supposing the root-cells of a Cereal plant and those of a Leguminous plant to take up the same amount of silica from the soil, the quantity of that ingredient would speedily be found to be greater in the Cereal than in the Leguminous plant, because the cells of the former can appropriate silica, and by osmosis store it up in the epidermal tissues, while the cells of the latter, having different osmotic relations to silica, soon become saturated and can take up no more. On the same principle we see cells in juxtaposition containing very different ingredients, which yet do not mix because the conditions for endosmosis are in some way or other not favourable.

Influence of Evaporation.—Schlösing says that the power of absorbing mineral ingredients from the soil is diminished by limiting the process

of evaporation, as when plants are grown under a bell-glass. Rauwenhoff also states that absorption exceeds transpiration in amount in proportion as the *pressure* is greater, and where the latter is slight evaporation is in excess.

Root-action.—It has been shown that absorption of fluids takes place near the extremities of the finest rootlets above the inert root-cap, and by means of the root-hairs. But the water in the soil is often nearly pure water, or, at least, contains little admixture of mineral matter, though more or less impregnated with gases. Again, many of the ingredients of the soil, such as silica for instance, are insoluble in pure water. How then do these substances gain access, as we know they do, to the interior of the plant? They must be derived from without and in a liquid form. The explanation now given is, that the minute rootlets and root-hairs insinuate themselves between the particles of soil, absorb the water there situated with its minute proportion of dissolved mineral matter. Further, these root-hairs come into close contact with the minute particles of soil, and, by virtue of some processes of excretion not yet thoroughly examined, they excrete a substance, gaseous or liquid, which effects the solution of the mineral substance in the particle of soil. An exhalation of carbonic dioxide from the roots, conjoined with the water in the soil, would effect the solution of lime, for instance. In this way the furrows and impressions on the surface of marble made by roots is explained. The opinion that root excretions exist, at one time denied, may thus be correct; but as they appear to be only excreted when required, and are used up in the process of solution, their presence in the soil is not manifested any more than that of the gastric juice in an empty stomach.

Absorption by Leaves.—The leaves and other green parts of the higher plants do not appear, as a rule, to absorb liquids all the time the roots are in action, but if root-absorption be insufficient then absorption by the leaves takes place. The good effect of syringing plants in hothouses seems rather to depend on the check given to undue evaporation than to absorption, the structure of the epidermis being generally unfavourable for that process. Whether leaves absorb even watery vapour to any great extent is questionable; but it is certain that they absorb gases, including ammonia, though, under ordinary circumstances, only in very small quantities (Mayer), and that a very large proportion of the carbon which is consumed by green plants is taken into the system, in the form of carbonic dioxide gas, by the leaves and green shoots.

The entrance of gases into the cells is attributable, through their solubility in water, to endosmotic action; while the laws of diffusion of gases provide for their entrance into the intercellular passages, which brings them into contact with the deeper-seated cells.

Sect. 5. Diffusion of Fluids in Plants.

Diffusion in Aquatic and Cellular Plants.—In aquatic plants the entire surface is employed in absorption; and the liberation of gases in the respiratory or other processes being accompanied by condensation of the cell-contents, *endosmotic* action is kept up constantly during active vegetation.

In the Cellular plants, such as Lichens, Fungi, and even in Mosses and Hepaticæ, the diffusion of the fluids would appear to be a result of simple endosmotic action continued from cell to cell in more or less complex series; and in plants growing in air, evaporation of gases increases the density of the contents of the last or uppermost cells of the chain.

Diffusion in Vascular Plants.—In plants with well-developed stems and roots, the liquid nutriment is absorbed by the latter, and the movements which the absorbed fluids have to make are much more complex, not only from the greater variety of forms of tissue through which they have to pass, but from the multiplied details of the interchanges with elaborated matters arising from the scattered distribution of the leaves over the axis.

Ascent of the Sap.—As so large a quantity of water is absorbed by the roots from below, it is clear that the diffusion of that fluid (or *sap*, as it is now called) must in the first instance be in an upward direction; hence the phrase *ascent of the sap*. The main current of the watery sap, is upwards from the root, through the stem and branches, to the leaves, wherein, owing to the changes it there undergoes and which will be hereafter alluded to, its character becomes altered and the direction of its current is varied according to the requirements of different parts of the plant, &c.

The term sap is retained for convenience' sake; but it must be remembered that there is no homogeneous fluid, either ascending or descending, crude or elaborated, of similar constitution in all parts of the plant, corresponding to the blood of animals. The sap varies in constitution in different parts of the same plant at the same time. In like manner there is no continuous system of tubes in which sap could "circulate." In spring, when vegetation is most active, or, at other times, when special circumstances favour growth in particular places, a current of watery sap, containing relatively little of the matters formed in consequence of leaf-action, is specially manifest; and as the ends of the shoots and buds are at this period centres of activity, so the flow is mainly an upward one. In autumn, when consolidation of tissues and storage of nutritive matters are the chief operations of the plant, there is an increased necessity for the presence of matters formed in consequence of leaf-action, and the flow is to a large extent a downward one. But there is no absolute difference between crude and elaborated saps, and no absolutely fixed course for them to take. The ascending sap, so called, which is so manifest in

spring, consists principally of water pumped up from the roots to supply the requirements of the growing cells, and the excess of it is evaporated when the leaves expand; but though mainly watery, it contains some mineral matters, and also some ingredients which must be derived from the action of the leaves of the preceding season.

The upward direction of the *watery sap*, therefore, and still more the downward current of the *elaborated sap*, must be understood in a general sense as indicating the prevailing direction of the currents. A more strictly correct expression would be to say that the sap, including all the liquid nutritive juices of the plant, moves in the direction in which circumstances are most favourable to its flow, and to those spots where the sap is most needed for the nutritive processes of the plant, or for purposes of storage, as will be more fully explained in succeeding paragraphs.

Causes of Ascent.—The causes producing the ascent of the sap are manifold. They vary not only in their nature, but, at different times, in different parts of the same plant and under varying circumstances. They act also separately or in conjunction. We will first of all allude to the inducing causes separately, and then indicate how, when, and where they act. *Endosmotic action* consequent on the absorption of fluids by the root is on all hands admitted to play the principal share in the diffusion of fluids throughout the plant. *Capillary action* and *Imbibition* facilitate the upward passage in or between the fibro-vascular tissues. *Pressure*, whether exerted by the tension of the cell-walls upon their contents, and itself consequent on endosmosis, or as the result of increased temperature, which expands the air in the stem, forces the fluids to move in the direction of least resistance. The *oscillations* produced by the swaying of the branches, petioles, &c. by the wind also occasion *intermittent pressure*, to which Mr. Herbert Spencer attributes an upward thrust of the sap towards the point of least obstruction.

The profuse *evaporation or transpiration* of watery vapour from the leaves is a powerful agent in producing an upward flow of fluid to replace that which is lost in the manner indicated. The *extravasation* or *exudation* of sap consequent on the mechanical strains effected by the wind also give rise to a current of sap from below. *Chemical actions*, such as the transformation of starch into sugar &c., necessitate a supply of water and create osmotic currents of that fluid.

Force of upward current.—The roots take an important share in promoting the upward flow of the spring sap. If, in spring, we notice the surface of stumps of timber-trees which have been sawn off in the preceding autumn, we find the cut surfaces wet with abundant exudation from the outer layers of the wood; and experiments made upon the cut ends of branches, by Hales and others, show that the sap rises in them with very considerable force—in the case of the Vine, supporting a column of mercury 26 inches in height. Clarke's more recent researches indicate

a still greater force, as, in one case, in a Vine he found the force of ascent sufficient to balance a column of water 48–50 feet in height. The quantity obtained from a Birch tree 75 feet high, from November to May, was 1486 lb., in one day 63 lb. being collected. The force and amount are subject to diurnal variations. It is evident that the spring current, at least, is partly owing to absorption by the roots, in the cells of which decomposition and solution of starch are effected, and which must in consequence absorb water greedily; the engorgement of the tissues may cause the liquids to be forced into and upwards along the course of the vessels and ducts.

In woody stems osmose also comes into play in conjunction with capillary action and pressure dependent on the various causes before named. Pressure resulting from increased temperature is illustrated by the circumstance that the flow of sap in the trunks of trees is greatest during the daytime, when the trunk absorbs the sun's heat by its rough surface, and least at night, when the tree is cooled by radiation. In the leaves the transpiration and the movements effected by the wind afford the main causes for the rush of sap. In the expanding leaf-buds, and in all portions of the plant where vegetation is going on actively and where in consequence large quantities of nutriment are required, the chemical transformation of the cell-contents, which renders them available for nutritive purposes, necessitates a large quantity of water; and in consequence an endosmotic current is produced. This chemical action does not necessarily occur at the very point where growth is most active, generally, indeed, elsewhere, in what may be termed the store-cells, so that a current is determined from the store-cells to the growing points.

The transfers just alluded to may be compared to a row of firemen handing on pails of water, in the absence of a *hose* or continuous pipe, such as is represented by the blood-vessels of an animal.

The *spring ascent of sap* in Dicotyledons is partly to be accounted for by the solution of starch, or the decomposition of fixed oil &c., in the buds and cambium-region, as above mentioned (just as occurs in the root or in a seed beginning to germinate). But, as has been observed by Von Mohl, the inspissated juices thus formed do not lie in the sap-wood wherein the ascending current flows, but in the cambium-layers, where the elaborated sap *descends*; and it is not clear why the ascending fluid, if moved by endosmose alone, does not pass out laterally into the cambium as soon as it reaches the stem. That the buds, however, do exert this attractive force is seen by the influence of the heat of a greenhouse in causing the flow of sap in a Vine which is planted with its roots outside the house, and its stem brought inside and trained there.

Transpiration.—In the leaves (and green portions of plants generally) the very important phenomena of evaporation or transpiration of watery vapours occurs, and constitutes probably the most important agent of all in causing the supply and diffusion of food in plants. It has been stated above that plants absorb their liquid food by their roots; therefore, under equal external conditions, a plant should receive the nutrient matters derived from its liquid food in the ratio of the quantity of water passing through its tissues and evaporated from its leaves &c., since the water

passes off almost as pure vapour, and, at all events, leaves its mineral constituents behind. The amount of evaporation is remarkably great, and accounts in some degree for the sustenance of plants by such extremely dilute solutions of their nutrient matters as they find in the soil.

Amount of Transpiration.—The experiments of Lawes and Gilbert give the following average daily loss of water in grains in the months indicated, in pots of unmanured soil, the first line from *Wheat*, the second from *Peas*:—

March 19th to March 28th.	March 28th to April 28th.	April 28th to May 25th.	May 25th to June 28th.	June 28th to July 28th.	July 28th to Aug. 11th.	Aug. 11th to Sept. 7th.
14·3	40·9	162·4	1177·4	1535·3	1101·4	230·9
11·2	42·9	106·4	1079·8	2092·7	377·2	—

The total amount of water given off during the whole period of 172 days (March 19 to Sept. 7) was, by the *Wheat*, 113,527 grains, by the *Peas*, 109,082 grains. The total quantity of mineral ash from each of the samples was, *Wheat*, 36·49 grains, and *Peas*, 43·16 grains, which shows that the Wheat took up 32·14 grains and the Peas 39·57 grains of mineral matter in every 100,000 grains of water which evaporated from it.

Other elaborate experiments of the same observers, recorded in the Journal of the Horticultural Society for 1851, show that evergreen trees transpire less than deciduous trees, and that great differences are manifested in different plants according to temperature. The maximum of evaporation does not always coincide with the maximum temperature. It was also found that plants cultivated without manure frequently evaporated more than those to which manure was applied; and, further, that under a purely mineral manure more water was transpired than when a mixed mineral and ammoniacal manure was used, so that the more abundant the food the less water transpired. Dehérain shows that, as a rule, the amount transpired is greater from the younger than the older leaves. Haberlandt, in his experiments on this subject, shows that young growing Cereals before the period of flowering transpire most, and least of all after that process, the relative proportion of root or absorbing organs as compared to transpiring organs being then greatest. The four plants examined by M. Haberlandt evaporated in 24 hours per 100 square centimetres during the whole period of vegetation (90 days) as follows:—Barley 3794, Wheat 3532, Rye 2849, Oats 2666 grammes. But considered in relation to the surface of the plants, the Oat evaporated 2277, the Barley 1236, the Wheat 1179, and the Rye 834 grammes per plant during the same period. Supposing a million plants on a hectare (a hectare$=2\frac{1}{2}$ acres about), the loss of water, according to the above calculations, over that amount of surface would be:—Rye 83,490, Wheat 1,179,920, Barley 1,236,710, and Oats 2,277,760 kilogrammes, which corresponds to a rainfall respectively of 83·5 millimetres, 118 millims., 123·7 millims., and 227·8 millims. In all cases great variations, both as to absorption and transpiration, occur in different individuals of the same species.

Circumstances regulating Transpiration.—The amount of transpiration depends on the amount absorbed, the quantity of water in the tissues, the age of the plant, the amount of surface exposed (Asa Gray calculated that a moderate sized Elm-tree bore seven millions of leaves, the total surface being equal to 5 acres), the nature of the epidermis, the texture of the leaf, &c.: thus it is usually greatest from the lower surfaces of leaves, which are provided with the greatest number of stomata. *External conditions*, such as the degree of moisture in or the temperature of the air, exert great influence on transpiration; the drier and hotter the atmosphere, the greater the transpiration; but, according to McNab, plants exposed to the sun transpire most in a moist atmosphere, while in the shade transpiration ceases when the atmosphere is loaded with watery vapour. Light also has great effect on the quantity evaporated. McNab's experiments, however, show that the rate of ascent of the watery sap is not checked by placing the branch in darkness for a short time. M. Wiesner shows that part of the light which traverses the chlorophyll is transformed into heat, as a consequence of which there results a rise of temperature, and an increased tension in the watery vapour in the intercellular passages occurs. The excess of vapour escapes by means of the stomata. A plant may, as shown by McNab and Dehérain, transpire in a saturated atmosphere, but only under the influence of light.

M. Wiesner has studied transpiration in three different ways:—1, by comparing that of green plants with that of blanched ones; 2, by exposing the plants in the solar spectrum; and 3, by placing them behind solutions of chlorophyll. By these different ways, he has arrived at the same results, viz.:—that the presence of chlorophyll markedly increases the action of the light on transpiration; that it is the rays which correspond to the absorption-band of the chlorophyllian spectrum, and not the most luminous rays, which excite transpiration; and lastly, that the rays which have traversed a solution of chlorophyll have only a slight influence on transpiration. Other colouring-matters, as xanthophyll, for instance, may act in the same way as chlorophyll, but to a less extent. The opening of the stomata may accelerate the transpiration; but the very marked transpiration of young Maize plants, the stomata of which were closed, and the slight transpiration of a *Hartwegia comosa*, the stomata of which were widely open in obscurity, suffice to show that this cannot be the principal cause of the transpiration in the light. In a very positive manner, but in a less degree than in the case of the luminous rays, the obscure calorific rays act. As to the chemical rays beyond the violet their action is null or very slight. Whatever may be the nature of the rays, they always act in raising the temperature of the tissues.

In spring, before the expansion of the buds, absorption is necessarily greater than transpiration; the water in such a case is stored in the stem, where it is made available for the expanding buds and growing tissues generally. In summer the transpiration is greater than the absorption; and then the leaves depend for their supply on the stores in the stem, or, failing that, they wither. Even in winter, provided the stem be not absolutely frozen, there is a motion of the juices, dependent to a great extent on the temperature of the soil, which is always in that season higher than that of the air, and it increases in amount from the surface downwards.

The relation of the *composition of the fluids* of the plant to the amount of transpiration has lately been studied by M. Burgenstein, by growing plants in saline solutions, taking care to prevent all evaporation except from the leaves of the plant, and then weighing the apparatus and plants daily so as to estimate the loss. Acids were found to increase the evaporation, alkalies to diminish it, other things being equal. Saline solutions act variously, according to the nature of the salt and the concentration of the solution, transpiration attaining a maximum at a certain degree of concentration and diminishing after that. In a mixed saline solution, or complete nutritive fluid, however diluted, the quantity of water transpired is invariably less than when the plants are grown in distilled water.

Tissues through which the Sap flows.—As regards the special tissues through which the sap flows, the experiments of Hoffmann and others indicate that a very uniform diffusion of fluids takes place in the Cellular plants and in the Mosses. But the last-named physiologist found that in the plants possessed of fibro-vascular bundles, the fluids passed up in the first instance from the roots chiefly in the prosenchymatous cellular constituents or soft bast-cells of the bundles. These experiments were made by causing the plants to absorb potassic ferrocyanide; and then, by treating sections of them with a per-salt of iron, the course of the sap was shown by the local appearance of *Prussian blue*.

Unger's experiments, in which he caused plants to absord the red juice of the berries of *Phytolacca*, gave the same results. As a rule, it was found by both observers that the fluids did not pass by the spiral vessels themselves, unless the continuity of the absorbing surface of the roots had been destroyed. Herbert Spencer's experiments, however, show that the passage through the vessels is much more rapid than through the cellular tissue. Where cut branches are caused to absorb, the fluids rise in the open vessels and ducts by simple capillarity. In McNab's experiments the ascending current was found to pass only through the woody portion of the fibro-vascular bundles and not through the liber.

The *spiral* and other *vessels* do not always participate in the diffusion of the juices; but in the commencement of the growing-season (with us, in spring), the whole tissue becoming gorged with fluid, the vessels are commonly found full of sap. In the regular steady course of vegetation the spiral vessels are usually found filled with air.

The *intercellular passages* are also filled with air, except under peculiar circumstances, and therefore take no part in the distribution of the sap.

The experiments which have been made to ascertain the course of the fluids absorbed by the *roots*, tend to show that the sap passes upward in the elongated cells associated with vessels in the fibro-vascular bundles, towards and into the leaves and other organs. The distribution of the fluids must therefore be very different in stems differently organized as regards the arrangement of these bundles. In Monocotyledons we find a series of isolated streams; in Dicotyledons the fluids ascend in a much freer and wider course, in the more abundant wood of the regularly arranged circle of bundles. A further diversity arises from the changes which take place in stems with age: in Dicotyledons the inner layers of wood

generally become converted in the course of time into *heart-wood*, the solidity of which obstructs the passage of fluids, which then ascend chiefly in the outer, younger layers of wood, which constitute the *alburnum* or sap-wood.

This is illustrated by the vegetation of hollow Dicotyledonous trees, in which a sufficient layer of young wood remains within the bark to carry up the absorbed fluids. It is found that the careful removal of the heart-wood of trees does not prevent the supply of liquid to the branches from the roots; but if the layers of sap-wood are removed, the upper parts of the tree die from desiccation, even when the bark is left uninjured except to such an extent as is sufficient to allow of removing the wood beneath. The removal of a ring of bark does not prevent the ascent of fluid, but, as will be noticed presently, arrests the downward distribution.

A certain amount of *lateral diffusion* takes place from the ascending current, supplying the surrounding tissues with water, and, perhaps, nitrogenous materials; but this point is not clear.

Crude Sap.—The fluid which is found in the sap-wood of Dicotyledons is of a watery character, containing dextrine and sugar, but not starch, chlorophyll, or any colouring-matter. It may contain matters dissolved out in its course through the tissues, and thus have a nutritive character from the admixture of matters stored up in the previous season in the wood-cells, &c. It contains also mineral salts absorbed by the roots, in an undecomposed condition, at considerable heights in the stem. This fluid is called *crude sap*, and occurs in especial abundance at the time (spring) when the renewed chemical activity in the developing cellular tissues causes an increased absorption of fluids.

This *crude sap* flows out freely from incisions into the sap-wood of Dicotyledonous trees in spring, and sometimes spontaneously bursts forth in a kind of overflow, as in what gardeners call "bleeding" of Vines, Birches, &c.

The crude sap becomes more and more condensed as it ascends in the stem and other organs. In the leaves and other green parts it undergoes a most important transformation, loses by transpiration much of its water, and receives a new element in its composition, of the highest importance to it as material for development, namely carbon, derived from the carbonic dioxide absorbed by the leaves and decomposed there in sunlight, with the liberation of oxygen.

Descending Sap.—The nature of the progress of the sap from the leaves into the *cambium-region* of the stem and other parts is at present obscure. Some authors, indeed, totally deny that the elaborated sap descends at all; but this is in contradiction to all experience and observation. All experiments which have been made favour the opinion that there is a descent of sap elaborated in the leaves, in Dicotyledons at least, in that part of the fibro-vascular bundles coinciding with the cambium-ring of the

stem—that is, in the cambium-layer of the wood and in the internal tissue of the bark. This supplies the material for the development of new wood in the fibro-vascular layers; and this elaborated sap evidently passes not only downward through the latticed vessels, sieve tubes, vasa propria, and conducting cells, but inward, by lateral transmission (since we find in autumn starch-granules laid up in the medullary rays between the wedges of developed wood), and also upwards when growth is going on, or where reserve material has to be accumulated.

The sap therefore is transferred from place to place in varying directions in Dicotyledons, not in a proper system of vessels, but by a series of disturbances and restorations of equilibrium in a mass of permeable tissues. The changes are dependent upon local physical, chemical, and developmental actions.

The evidence of a descent of elaborated sap is overwhelming. The simplest proof, that of removing a ring of bark, which causes the arrest of development of wood below the ring, is borne out by all variations of it. *Ringing* fruit-trees in this way causes a swelling of the tissues and a temporary increase of product of fruit *above* or on the distal side of the wound, from the accumulation of the elaborated matter. The formation of tubers in the Potato and similar plants is prevented by interrupting the continuity of the cortical layers; and when bark is removed in patches, and the surface becomes gradually grown over by new wood, the greater part of the new growth comes from the upper side. Still a descending current is not the only direction in which nutritive fluids flow; for, as has been already stated, the flow may be in any direction, and new wood may be formed in place without immediate connexion with any descending current.

It is Mulder's view that all the nitrogenous constituents of plants are not only absorbed by the roots, but assimilated there at once, and that carbon is fixed in the green organs—then, that a continual interchange goes on from above and below, the roots supplying protoplasmic matters which originate all organic phenomena, while the leaves send down the ternary compounds (C H O) which afford the material for cell-membrane, starch, &c. This author attributes the distribution to simple endosmose; but this does not account for the passage of crude sap through the alburnum, and of elaborated nutriment through the inner bark. Other authors consider that organic substances (carbo-hydrates, albuminoids, &c.) are formed in the leaves; in such a case a descent of the sap must of necessity occur. The transfer from one leaf to another of such substances as glucose, albumen, phosphates, &c. may be accounted for by evaporation.

Sachs states that the elaborated sap in the cellular tissue is different from that in the vascular; "the parenchymatous tissues have," says he, "an acid sap, containing sugar, starch, oil, vegetable acids," &c. The vascular and prosenchymatous tissues, including the "vasa propria" and clathrate cells and other elements of the soft bast, have an alkaline sap. The sap passing through these tissues is of an albuminous or nitrogenous nature. Other physiologists, however, doubt whether any such sharply defined dual nature of the elaborated sap exists, though admitting the large share

which the vasa propria fill in the descent of the elaborated juices. It is clear, however, that the currents of the sap must vary according to the different anatomical disposition of the tissues.

Summary.—We may conclude by repeating that the nutrient fluids in plants follow certain directions, according to the structure and arrangement of the tissues, the place where evaporation is most active, the locality of the sources of nutriment and of growth or other action; and that as regards the elaborated fluid the movement may be, 1, from the place of formation to that of consumption, or, 2, to the store-cells or reservoirs, or, 3, from these latter to the place of consumption. The ascending, descending, or horizontal direction of the currents is therefore a secondary matter.

To illustrate the movement and transference of nutrient matters, allusion may here be made to the researches of M. A. Gris on the production and utilization of starch, &c. This observer finds that in winter-time the medullary rays, wood, and pith are all filled with starch-grains. These diminish in spring, but are afterwards replaced during the summer. He concludes from this that there are two special movements of the nutrient substances, as illustrated by their formation in summer and their absorption in the following spring.

Sect. 6. Elaboration of the Food.

Exhalation of Oxygen.—When green plants are placed in water containing dissolved carbonic dioxide, and exposed to sunlight, they give off oxygen gas.

This may be readily observed in *Vallisneria* and other submerged green plants grown in glass jars, a continuous stream of bubbles escaping from the plants when standing in the sunshine. The frothy masses of Confervæ, borne up to the surface of freshwater pools in sunny weather by the entangled bubbles of oxygen, afford another common instance.

The absorption of carbonic dioxide, and the elimination of oxygen in the case of aquatic plants, and also in that of leathery leaves as in the Cherry Laurel, where there are comparatively few stomata, take place chiefly or entirely on the upper surface.

Where no carbonic dioxide exists, as in boiled or distilled water, no oxygen is liberated. Leafy shoots remaining attached to trees, but enclosed in close glass globes, increase the percentage of oxygen in the globes when exposed to daylight; and cut shoots with the lower ends placed in water containing carbonic dioxide in solution give off more oxygen than when the lower ends are dipped in water devoid of that gas.

The oxygen exhaled by leaves &c. is formed at the moment of its liberation; for Confervæ, which have no air-passages, and other plants which have had their air-passages exhausted by the air-pump, give off oxygen under the above circumstances. Fragments of leaves perform the same function so long as their organization is uninjured, while the destruction of the cells by pressure &c. stops the action. The epidermal cells exhale no oxygen.

Effect of various Rays of the Spectrum.—The unlike influence of the different rays of the spectrum is very remarkable. According to Daubeny and Draper, whose observations have been confirmed by numerous observers, sunlight acts in proportion to its illuminating power in the deoxidating process, which appears to be just the reverse of what occurs in the reducing action of light upon silver. The yellow rays are almost as powerful as white light; while the more refrangible rays, blue, violet, &c., have little or no effect on the emission of oxygen, though it is probable they may exert great influence on the chemical transformations which follow that process, and have a directly favourable influence on heliotropic curvatures, periodic movements, currents of protoplasm, &c. (Pfeffer, Baranetsky). In green light the leaves emit carbonic dioxide gas, as in darkness. Diffused light is rich in the more refrangible rays, and hence causes a scanty emission of oxygen. Prillieux, however, asserts that the amount of oxygen emitted by light of different colours is in direct proportion to their illuminating-power, and that the effect of the yellow and red rays in causing the disengagement of oxygen is due to their luminous intensity. A corresponding fact has been noticed with regard to the evaporation of water, so that the two phenomena would appear to be in some way connected. It has been found that starch is formed under white, yellow, or blue light, but in different proportions and with different degrees of rapidity, its formation under the influence of blue light being much slower than under white light.

Quantity of Oxygen.—The quantity of oxygen given off bears a definite proportion to the carbonic dioxide absorbed by a plant; but excess of carbonic dioxide becomes obnoxious to health.

Elimination of Nitrogen, &c.—It would appear that nitrogen is also given off by plants exposed to sunlight. Draper observed considerable quantities exhaled; and Cloez and Gratiolet noticed more than was attributable to air accidentally present in the intercellular passages. According to Corenwinder the proportion of nitrogenous matter and phosphates gradually decreases from the time of the opening of the leaves till their fall.

Boussingault asserts that in the case of marsh plants a small proportion of *carbonic oxide* is exhaled by the green parts of plants, but probably not under normal comditions.

Elimination of Carbonic Dioxide.—When the influence of the sun is withheld from green plants they cease to give off oxygen; carbonic dioxide is now not absorbed but exhaled, oxygen being absorbed from the surrounding medium.

Some entire plants destitute of chlorophyll (Fungi and parasites) and certain parts of most others (buds, roots, flowers, germinating seeds, &c.) absorb oxygen at all times and exhale carbonic dioxide. and thus become, like animals, an apparatus for the combustion of carbon and hydrogen.

The carbonic dioxide given off from the interior of stems, roots,

&c. by day is probably reabsorbed and decomposed in the green parts before it arrives at the surface of the leaves.

According to De Saussure, if a plant is kept in a perfectly closed jar containing a measured quantity of atmospheric air, for several days and nights (an equal number of each), no change is found in the volume or composition of the air; the plant has exhaled oxygen by day and absorbed it by night, and exhaled carbonic dioxide by night and decomposed it by day, in equal proportion. But if this plant is watered with solution of carbonic dioxide, or this gas be added to the air, the quantity of oxygen in the air becomes increased. Under ordinary circumstances the leaves decompose by day much more carbonic dioxide than they exhale by night. The disengagement of oxygen has been observed in some aquatic plants to go on in the dark for some hours after exposure to the sun. The sun's light is thus stored away in the plant and rendered available in some form or other when wanted.

If plants are placed under such circumstances that they cannot decompose carbonic dioxide and exhale oxygen (by excluding light from them, or by confining them in vessels deprived of carbonic dioxide), they never acquire proper development; no green colour appears (they are etiolated), little or no woody matter is formed in the walls of the cells, and the whole energy is consumed in pushing out weak watery shoots; scarcely any of the peculiar resinous, milky, or other secretions are produced; and plants can only subsist under these circumstances when supplied with organic nutriment.

We see this when shoots are developed from Potato-tubers in the dark, in the cultivation of Celery and other blanched plants, &c. But in some cases it would seem that plants not only have the power of acquiring carbon by their surfaces, but that they have also the power of growing in an atmosphere deprived of carbonic dioxide provided they can assimilate the carbon from the carbonic dioxide circulating in their own tissues (Saussure, Corenwinder).

A moderate addition of carbonic dioxide to the food of a plant, with free access of light and air, is mostly accompanied by acceleration of the nutrient processes and a more abundant liberation of oxygen.

Many green plants will flourish in sunlight on water and carbonic dioxide alone. Saussure found that the organic matter of plants increased in the proportion of 2 to 1 of the carbon contained in the carbonic dioxide; the elements of water being combined with the carbon.

Effect of Nitrogen and of a want of Air.—When plants are placed in pure nitrogen gas, or *in vacuo*, all the functions of vegetation are arrested: not only do the chemical actions above noticed cease, but irritability, like that of the Sensitive-plants &c., is lost, and the plant decays. Even shoots separately enclosed suffer in the same way. The death occurs especially early when the plant is kept in the dark.

This accounts in some degree for the injury resulting from roots growing down too deeply into the ground, as is often observed with fruit-trees.

Assimilation and Respiration.—It appears, therefore, that there are two opposed sets of operations in which plants have close and

important relations with the atmosphere: in the one, occurring when they are exposed to the sun's light, oxygen is liberated and carbon is fixed, which must be regarded as a process of *assimilation*; in the other, oxygen is absorbed and carbonic dioxide is exhaled, as in the *respiration* of animals. The plant is thus subjected to two opposing forces in connexion with the *chlorophyllian* and the *general* respiration—the one tending to add, the other to abstract material; and, according to the proportion between these two forces, governed as they are by the variations of light and temperature, a plant will either emit oxygen or carbonic dioxide in variable proportions. In a feebly illuminated spot a plant may remain nearly in equilibrium for months. In absolute darkness, the eliminating force being the only one in operation, the plant can only live upon its own constituents, emit carbonic dioxide by their combustion, and finally perish without increase of weight (Boussingault). Fixation of carbon is absolutely necessary for the production of new ternary compounds (C H O), but elimination of carbonic dioxide appears absolutely requisite for the maintenance of the life of the plant. The elimination of carbonic dioxide is increased by heat, and is most conspicuous at night or in darkness, but it never entirely ceases during the life of the leaf. In the daytime the quantity eliminated being small, it is entirely taken up and again deoxidized by the chlorophyll.

According to Corenwinder the season of vegetation may be divided into two periods: the first that of growth, when the nitrogenous matter is in excess but rapidly diminishing, the period when the true respiratory process is most vigorous; the second, the period of maturity, when the process of assimilation dependent on the deoxidation of carbonic dioxide by chlorophyll is at its height, the relative proportion of carbonaceous to other constituents being then greatest.

The passage of gases, of whatever nature and in whichever direction, is dependent on the laws of diffusion; the cuticle of the leaf in these cases acts as a dialyzer or filter, checking evaporation, but permitting the passage of gases.

Effect of Deoxidation.—The assimilative process, in which oxygen is liberated, accompanied by accumulation of carbon in the tissues, is evidently related to the formation of the remarkable series of neutral ternary compounds which constitute the great bulk of the substance of plants, and, further, to the production of the more obscure and far more complex and varied series of substances formed by a further removal of oxygen from the compounds of the first class.

The composition of the principal constituents of cellular tissues, and

the substances found in the watery cell-sap, is generally such that they may be regarded as consisting of carbon *plus* the elements of water; but it is by no means to be regarded as settled that they are secondary compounds formed by the union of water with carbon.

The formation of crystalline acids, such as oxalic acid &c., is theoretically accounted for by a process of deoxidation. A further deoxidation of carbonic dioxide and water would result in the formation of the different carbo-hydrates, cellulose, starch, sugar, &c. A still greater loss of oxygen would account for the formation of the vegetable fats &c.

The formation of the neutral ternary compounds being constantly in relation to the absorption of carbonic dioxide and the passage of water through the tissues, with the exhalation of oxygen, it has been assumed that assimilation of carbon in the green parts of plants is the result of decomposition of carbonic dioxide and of the combination of the carbon with water. As Liebig, however, indicated, water is far more easily decomposed than carbonic dioxide; and perhaps the oxygen may be derived from that, its hydrogen uniting with carbonic dioxide.

There is no evidence to show which view is correct. In the next place, Draper regards the decomposition of carbonic acid as a process resulting from *contact-action* or *fermentation* excited by the nitrogenous protoplasm, accompanied by a waste of the latter, in which nitrogen is liberated. Mulder, on the other hand, believes that the carbonic dioxide enters into combination with some substance existing in the protoplasm, and that the oxygen is set free by the decomposition of this compound; for example, that chlorophyll is produced continually in sunshine, the wax associated with this being formed from starch, accompanied by a separation of oxygen, that this oxygen partly escapes and partly oxidizes the chlorophyll substance and causes it to become green.

Of these views, Draper's appears the most worthy of credit, as agreeing best with the phenomena observed in the cell-contents. Chlorophyll does not originate from starch, but usually *vice versâ*; and it is quite admissible to assume a deoxidating *contact-action* of the protoplasm under the influence of light, when we observe a distinct oxidizing *contact-action* of the same part of the cell-contents in the dark, as in the decomposition produced by the growth of the Yeast-plant (p. 552).

Nitrogenous Constituents.—As to the nitrogenous constituents of plants, we know little at present beyond the fact that they originally exist in the form of protoplasmic substance, which, according to Mulder, consists of modifications of the substance called proteine, known as vegetable albumen, fibrine, caseine, &c. They constitute the substance of the primordial utricle and the protoplasm, on which chiefly depend, in all probability, the vital and chemical activity of the cell-contents. These have the power of decomposing organic compounds by *contact-action*, and perhaps of causing new organic combinations. How they originate themselves is unknown; but it appears most probable that their source is either ammonia in combination with organic substances, or in some cases nitrates; and it is most probable that there is ground for Mulder's opinion that all actively vegetating cells (containing protoplasm) are capable of directly assimilating organic matters to some extent, whether exposed to light or not, as has been shown in the case of the carnivorous plants before alluded to (p. 560).

This seems borne out by the universal presence of these nitrogenous compounds in actively vegetating cells, in roots, parts of the flower, in cambium, &c., as well as in green organs. That the *crude sap* is found to contain uncombined ammoniacal salts high up in the stem in spring may result from the activity of the currents of fluid allowing part of them to flow on undecomposed, while a part only is assimilated in the roots.

Proteinaceous matters, it may now be stated with some confidence, when not directly absorbed, originate in the colourless protoplasm from the decomposition of sugar and ammonia salts, in the same manner as starch is formed in the chlorophyll under the influence of light. Pasteur, as we have seen, induced the formation of protoplasm in yeast-cells by supplying them with a saccharine solution and a nitrate or ammonia salt.

An animal of the simplest organization not only produces heat through respiration, and exhales carbonic dioxide, but a certain portion of the albumen it contains is modified by the respiratory combustion into a crystalline nitrogenous compound (*urea*). In the case of plants, *asparagin*, an amide, is formed in the darkness as a result of the general respiration, and this is as easily transformed into aspartate of ammonia as urea into its carbonate (Boussingault). This asparagin is a modification of the albuminoid matters stored up in the cotyledons, formed when a transfer of these matters is required, as in germination.

Our space compels us to restrict this Section within narrow limits, and we are obliged to omit any special reference to the application of these generalizations to the explanation of the facts of Agriculture*. The student is recommended to study works on physics and organic chemistry, as vegetable physiology is daily becoming more and more a subject for the physicist and chemist; and without a knowledge of the subjects treated of by students of these sciences, progress in vegetable physiology is impossible. What is specially wanted are experiments and analyses showing precisely what physical and chemical changes go on in the several parts of the plant at various stages of growth and their *rationale*.

Sect. 7. Secretion.

At the commencement of the periods of activity of plants, as when they shoot up from seeds, or when the new shoots are pushed out in spring, the whole product of the elaborating processes is devoted to the formation of new structure, to *growth*. As the season advances, the cell-forming activity slackens, the permanent tissues become consolidated by the formation of secondary deposits, and the parenchymatous tissues appear loaded with accumulated products of assimilation, such as chlorophyll, starch-granules, &c., which in annual plants are subsequently consumed in the maturation of the seeds, and in perennials are gathered together in autumn and stored up in those tissues which are to carry on the development in the succeeding season.

* The student will find a useful summary of chemical science applied to agriculture in a little work called 'How Crops Grow' (MacMillan).

Secretions.—The phenomena of growth have been dwelt upon incidentally in preceding Sections, and are further discussed in the next chapter; but we have here to speak of certain processes, occurring more or less extensively in plants, contemporaneously with growth, in which products are formed which are not, like starch, chlorophyll, &c., evidently transitory forms of assimilated substance. These substances, called by the general name of *secretions*, are of most varied kinds, and their relation to the economy of vegetable life is very obscure; but a brief notice of the most striking of them is indispensable.

A distinction is sometimes made between the peculiar products found in the interior of cells, and those which are accumulated in certain cases in intercellular passages or cavities, or upon the outer surface of cell-membranes, the former being called *secretions* and the latter *excretions*.

The principal substances secreted by plants are air, water, gum, sugar, volatile oils, balsams, resins, gum-resins, and salts, either entirely inorganic, or formed of combinations of mineral bases with organic acids, &c.; besides these there occur in individual Orders a multitude of alkaloids, neutral substances of various kinds, colouring-principles, &c.

Gases.—The liberation of gases into intercellular passages, cavities, &c. occurs both as a necessary accompaniment to the chemical decompositions going on in the cells, and as a special process connected with peculiar habit of plants &c., as in the *Utriculariæ*, in the air-sacs of *Fucus vesiculosus*, &c. The composition of the air found in the cavities of plants necessarily depends upon the external conditions, as under sunlight there is generally a greater proportion of oxygen than exists in common air, in the dark but excess of carbonic dioxide.

Water.—Water is given off in a liquid form by various plants, either from glandular papillæ, or from the general surface of leaves &c. In *Nepenthes distillatoria*, *Sarracenia*, &c. water is secreted in the pitchers wherein it accumulates. The leaves of various Musaceæ, Araceæ, Grasses and other Monocotyledons, *Tropæolum*, *Impatiens*, *Brassica oleracea*, &c. give off drops of water from the leaves. In *Caladium* there exist orifices at the points of the leaves, communicating with internal canals, whence great quantities of water flow (half a pint in one night). This water is of course contaminated with salts and small quantities of soluble organic matters.

Gum is usually poured out into and accumulated in intercellular passages, as in the Cycadaceæ, in the bark of the Acacias, Cherry, &c. When it is formed in large quantities, it bursts the tissues and exudes in the form of tears. The formation of the gum Tragacanth in the species of *Astragalus* is different from this, consisting of collenchymatous thickening of the cells of the pith and medullary rays, which swell by absorption of water, and burst out from the stem under certain circumstances. The peculiar organs called *cystolithes* have a gummy excretion as a basis, in the form of a clavate body, suspended in the interior of an enlarged cell by a cellulose pedicle; when mature these bodies are covered with

crystals of carbonate of lime: they are especially common in Urticaceæ, as in *Ficus elastica, Morus, Broussonetia*, &c.

Sugar, commonly occurring as one of the soluble forms of the assimilated ternary substances, is occasionally excreted, especially from the parts of flowers, such as the so-called nectaries. Through evaporation of water the sugar sometimes appears in a crystalline form. Grape-sugar (glucose) is apparently formed in the leaves by the combination of carbonic oxide and hydrogen, the former derived from the breaking up of carbonic dioxide, the latter derived from water. At other times it is formed from the metamorphosis of starch. It is supposed that from the glucose formed in the leaves the principal carbohydrates, such as cellulose, cuticular substance, some acids (as oxalic and formic), are derived from the oxidation of the glucose.

Sugar occurs commonly in the corolla-tubes of monopetalous flowers (Lilac &c.), on the nectariferous coronet of various plants, on the glands of petals like those of *Ranunculus*, *Parnassia*, &c., or in pits in the same situation, as in some Liliaceæ. On the leaves of various species of *Acacia* occur glands secreting sugar; and the same is the case in species of *Clerodendron*, Laurustinus, the lower surface of young leaves of *Prunus Laurocerasus*, &c. Various species of Ash (*Fraxinus*) and *Tamarix* excrete a great quantity of saccharine substance under the form of *manna*.

The wounds inflicted by insects (*Aphis*) also cause excretion of sugar from leaves, forming "honey-dew."

Pectose and **Pectase.**—Pectose is a gelatinous hydrocarbon insoluble in water, alcohol, and ether, found in unripe fruits, and in fleshy roots like carrots. By the agency of acids it is converted into *pectine*, which gives the viscid character to cooked fruits. *Pectase* is a peculiar ferment found in fruits, which transforms pectose into pectosic acid.

Volatile Oils are extremely numerous. They are ordinarily secreted in glands, either external or internal, situated on the herbaceous parts of plants. They are rarely pure substances, the essential oils usually containing dissolved resinous matters, camphor, or active principles of various kinds. The odours of plants and many of their most important qualities depend upon these secretions, which are generally peculiar to particular genera or Orders of plants, and not unfrequently differ in slight degrees, so as to be characteristic of particular species in an Order. The chemistry of the formation of these bodies is still very obscure. Some are hydrocarbons; others contain oxygen in addition; and sulphur plays an important part in many, especially in the Cruciferæ. The only general statement which can be made is, that the majority of the essential oils contain less oxygen in proportion to carbon and hydrogen than the dextrine and the other neutral ternary compounds, and that their production stands in a certain relation to the access of sunlight to the plants.

The Labiatæ with their external epidermal glands, the Hypericaceæ and Aurantiaceæ with their internal glands, the Umbelliferæ with the oleiferous vittæ in the fruit, the Terebinthaceæ, Rutaceæ, &c. are striking instances of the occurrence of essential oils in particular Orders.

Resins, solid or fluid (balsams), are very varied. They occur chiefly in intercellular passages, or in groups of cells especially devoted to the secretion of these products. Very little is known of the processes of their

formation; but the same generalities apply to them as to the essential oils with which they are not unfrequently associated.

Among the resin-producing Orders may be noticed especially the Coniferæ, the Leguminosæ (*Copaifera, Myroxylon, &c.*), Amyridaceæ, Guttiferæ, Styraceæ, Terebinthaceæ, Liliaceæ (*Aloe, Xanthorrhea*), &c.

Resinous and waxy matters are found in considerable abundance on the surface of the leaves or fruits of many plants. It is not clear at present how far these are to be regarded as proper excretions or as chemically metamorphosed epidermal structures.

Under this head falls the waxy coat of leaves and fruits which exhibit what is called a "bloom," as the leaves of Primulaceæ (*P. Auricula*, &c.), the fruits of the Plum, &c. The wax of the Wax Palm (*Ceroxylon*) is formed in flakes upon the surface of the stem.

Wax and resinous matters occur on the outer coat of the pollen of flowers; and the viscid surface presented by the epidermis of many plants, such as *Lychnis Viscaria*, some *Silenes*, &c., is attributable to similar causes.

Latex.—The so-called milky juices (latex) occurring in specially modified intercellular passages (p. 513) are of complex composition, containing essential oils, resins, gum-resins, starch-grains, extractive matters, alkaloids, proteinaceous compounds, caoutchouc, &c. suspended in water, forming a kind of emulsion. They are not opaque and milky in their natural state, but become so when exposed to air, and mostly assume a transparent resinous character when their watery constituents evaporate. Very different opinions have been expressed as to the nature of latex and the vessels containing it. By some it has been considered a nutritive fluid analogous to arterial blood, by others as of purely excrementitious nature. A third notion is founded on the comparison of the fluid in question with venous blood. Probably that view by which it is regarded as a fluid containing, mixed with matters of a directly nutritive character, others which are excrementitious in their nature (Sachs, Hanstein) is the most correct. Trécul holds that the laticiferous vessels are the analogues of the veins, and their contents equivalent to venous blood. He traces a contact and inosculation of the laticiferous vessels with the pitted ducts and other vessels. Latex from this point of view would be the residue of the sap after elaboration by the cells—the *caput mortuum* of the sap. Faivre's experiments show that the latex may flow in any direction, and not only through the bark, but through the wood and the pith (in *Ficus elastica*).

These juices abound especially in particular Orders, as in the Papaveraceæ, Euphorbiaceæ, roots of Cichoraceæ, Apocynaceæ, Urticaceæ, &c. Amongst the most important substances obtained by evaporating them to dryness are:—*opium* from *Papaver somniferum*, and *caoutchouc* from various Euphorbiaceæ, Urticaceæ, and Apocynaceæ; *gutta percha* from *Isonandra gutta*, &c.

Saline Matters.—The saline and purely mineral excretions of plants have been already referred to. They occur as incrustations of the cell-membranes, as silica in the Grasses, Equisetaceæ, Stellatæ, &c., or carbonate of lime in *Charæ, Corallinæ*. and in smaller quantities on the leaves of various Saxifrages. Crystals (*raphides*, p. 505), either of inor-

ganic salts or compounds of organic acids with lime &c., are frequently met with in the cellular tissues; but very little is known at present of the nature of their relation to the chemical processes of vegetation. Calcium oxalate may be regarded, according to Holzner and Hilgers, as a product of elimination, by means of which the superfluous lime is deposited in a solid form. This lime is set at liberty by the calcium phosphate absorbed, when this is decomposed to supply the phosphoric acid requisite for the new albuminoid materials. The lime so liberated is combined with the oxalic acid with which young tissues abound. Rauwenhoff shows that these *raphides* are wanting in plants grown in obscurity; which, therefore, is an indication of inability of the plant to absorb or decompose calcic phosphate.

The close relation of the vegetable acids, oxalic, malic, citric, &c., to carbonic dioxide, water, and the ternary assimilated substances has already been alluded to.

Tannin, or tannic acid, is a very frequent constituent of the woody tissues when their vital activity has ceased, and is perhaps a product of decomposition. It is formed in plants exposed to light as well as in those grown in obscurity, but in smaller proportions in the latter case. Oak, Sumach, *Rhus coriaria*, *Acacia catechu*, &c. owe their tanning properties to this substance. In fruits the proportion of tannin decreases as that of sugar increases, but it is not known what circumstances regulate the change. For the detection of tannin in the cells under the microscope, Sanio recommends that sections be macerated in potassic bichromate, which causes a reddish-brown precipitate in the cells, and which is consistent enough to allow of sections being made without extravasation and staining of adjacent tissues.

Speaking in general terms, it may be said that the immediate principles of plants may be grouped under three heads:—1, those in which oxygen is in excess—as pectin, pectose, tannin, and vegetable acids; 2, those in which H and O are in equal proportions—cellulose, starch, gum, sugar, lactic, acetic, quinic acids; and, 3, those where H is in excess—as in resins, essential oils, camphor, salicin, various alkaloids and colouring-matters.

CHAPTER III.

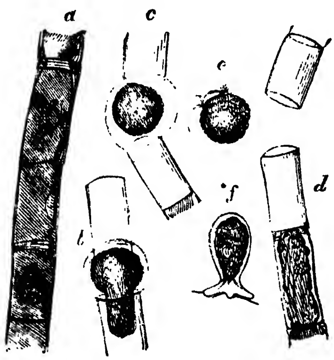
GROWTH AND DEVELOPMENT OF ORGANS.

Sect. 1. Development of Cells.

The formation of new cells takes place in several ways, though essentially the process always consists in the setting apart of the whole, or more frequently of a portion or portions of the protoplasm in one or other of the following manners:—1, by condensation or alteration of the molecular structure; 2, by segmentation or by both combined; and, 3, by the blending of the contents of one cell with those of another. In any case the mass of protoplasm newly set apart is sooner or later invested by a cellulose coat. It is hence convenient to treat of cell-formation under the heads of segregation, conjugation, segmentation, and free-cell formation.

Cell-formation by Segregation.—A certain portion (or portions) of the protoplasm is set apart from the rest, escapes ultimately from the cell-wall, lives independently for a time, and ultimately is invested with a cellulose coat. The zoospores of *Œdogonium*

Fig. 591.



Development of zoospore in *Œdogonium*: *a*, parent filament; *b*, a joint breaking across to emit its contents; *c*, a more advanced stage, the globular mass of contents (nascent zoospore) still within a cellulose pellicle; *d*, empty parent cell; *e*, the zoospore escaped from it, with its crown of cilia formed; *f*, the zoospore, after it has settled down, become encysted by a cellulose coat, and begun to grow into a new filament. Magn. 200 diam.

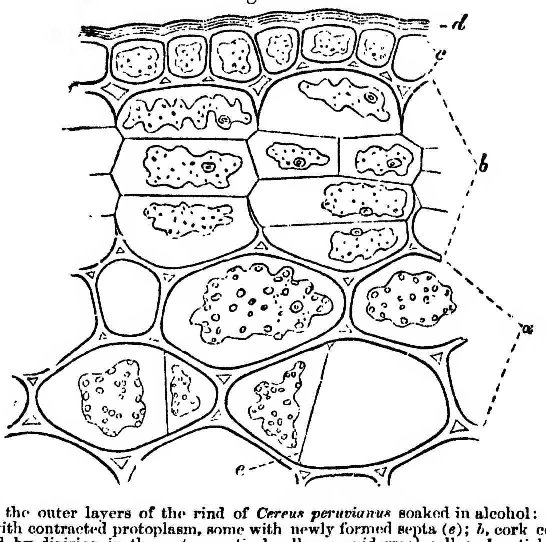
and other filamentous Algæ are formed in this manner (fig. 591). Sometimes the whole of the protoplasm escapes from the cavity of the cell, and ultimately forms a new cell. This is spoken of as *rejuvenescence.* The detached masses of protoplasm often move in an

amœboid manner, and swim about by the aid of ciliary projections, and it is not until they come to rest that they form a cellulose coat (fig. 591) and acquire the appearance of a completely formed cell.

Formation by Conjugation.—This mode of cell-formation, met with in some Algæ and in some Fungi (fig. 503, B, *b*: fig. 512, A, *c*, *d*), consists of the transfer of the protoplasmic contents of one cell into the cavity of an adjoining cell, and in the fusion or blending of the protoplasm of the one with that of the other. The spore so formed is called a *zygospore*. In place of a numerical increase an actual decrease occurs here, from the blending of two into one.

Cell-division or Segmentation.—This is the common mode of cell-formation in the vegetative system of plants, and occurs also in a slightly modified form in the formation of pollen. In this method of cell-formation the newly-formed cells remain for a time or permanently in contact with each other, and do not become free or

Fig. 592.

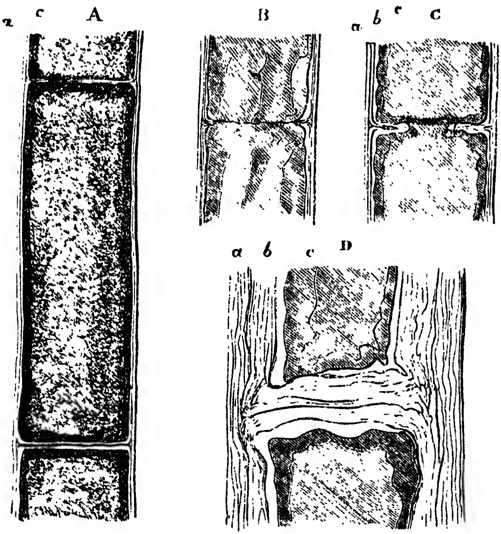


Section of the outer layers of the rind of *Cereus peruvianus* soaked in alcohol: *a*, cortical cells with contracted protoplasm, some with newly formed septa (*e*); *b*, cork cells newly formed by division in the outer cortical cells; *c*, epidermal cells; *d*, cuticle. Magn. 200 diam.

detached, at least at first. The process takes place in all growing parts of plants, but in the higher classes these regions are only accessible by dissection; in the lower, and especially in aquatic plants, we are able to observe the process of cell-division in living organisms in all its details; and it is in these that the phenomena

are most satisfactorily studied. Cell-division can only take place in a cell which retains its protoplasm in an active state, as in the cells constituting the *meristem* (p. 514). When the parent cell is about to produce two (or four, rarely more) new cells, the protoplasm separates from the cell-wall at the line bounding the plane of division, and advances inwards in the form of a narrow fold, until the portions of the fold coming from the different sides of the cell coalesce, so that the protoplasm is resolved into two (or more) closed utricles, together completely occupying the place of the original utricle. While the protoplasm is folding inward, it forms thicken-

Fig. 593.



Cell-division in *Cladophora glomerata.* A. Part of a filament in a natural condition: *a*, cell-membrane; *c*, primordial utricle or protoplasm; *x*, situation where division is about to take place. B & C. Stages of the formation of a septum at *x*, the filament having been treated with alcohol: *a*, wall of the parent cell; *b*, walls of the new cells; *c*, protoplasm. D. Septum of old filament treated with dilute sulphuric acid, to swell up and separate the laminæ of the cell-wall and contract the protoplasm: *a*, wall of parent cell; *b*, wall of daughter cells; *c*, protoplasm. Magn. 200 diam.

ing cellulose laminæ on the wall of the parent cell and on either side of the septum separating the cavities of the two new cells, formed by the infolded portions of the protoplasm (fig. 593). This takes place not only in the vegetative cells but also in the pollen. At other times the new dividing cell-wall is formed gradually, after the sudden division of the protoplasm into two or more portions,

so that the process of cell-division exhibits two principal modifications—that in which the new cell-wall is secreted during the division of the protoplasm, and that in which it is formed only after its complete segmentation.

This phenomenon may be traced very clearly in all its minutiæ in large species of Confervæ (*Cladophora*, fig. 593); and so far as we may judge from observations, extended from similar cases, through the accessible structures (nascent leaves, prothallia, &c.) of Mosses, Ferns, &c., up to what we can detect in sections of the tissues of the Phanerogamia, it is the general mode of subdivision of cells.

The principal varieties which this process exhibits depend on the character of the tissue to which the dividing cell belongs. In filamentous Confervoids this division takes place in most cases both in the end cell of a filament (apical growth) and in cells forming links further down (intercalary growth); in each case the parent cell elongates more or less beyond the ordinary measure before dividing, and the new cells each grow until they equal the adult length of the parent. In the branched *Cladophoræ* (fig. 512, C) &c. the parent cell sends out a lateral arm, which is at first a pouch with its cavity continuous with that of the parent; and this is subsequently shut off by a lateral septum formed in the manner above described.

The *basidiospores* of the Agarics &c., and the spores of *Penicillium*, *Botrytis*, and the allied forms of Fungi, are produced in the same way, as also are the *conidia* of the "Yeast-fungus," the new cells emerging like bubbles blown out from the wall of the parent cell, and becoming subsequently shut off by a similar process. In the Phanerogamia, the cells of the growing points, as of the apex of buds and roots, of the cambium-layer of the stem, &c., multiply while very minute, so that it is not so easy to trace the changes; but cell-division may be readily observed in the epidermal hairs of the highest plants, and the protoplasm is observed to be equally efficient as the agent of multiplication in these. The direction in which the division takes place is usually horizontal, sometimes oblique, rarely if ever strictly vertical. It will readily be surmised that the form of the organs and the mode in which they ramify may depend materially on the form of the terminal or apical cells, and on the direction in which they divide.

The production of complete cells within cells, the septa dividing the new chambers being continuous with new laminæ deposited on the old wall of the parent cells, may not only be observed directly in *Cladophora* (fig. 593, D), but is beautifully proved by allowing filaments of *Spirogyra* to decay in water; but these break up into lengths of eight, four, and two cells, and at last into single short cells, by the solution of the membranes from without inwards.

The softening and swelling up of these parent membranes doubtless give rise to the semigelatinous coat of many of the lower Algæ, especially the *Nostochineæ* and *Palmelleæ*. In the cells of the parenchymatous tissues of the higher plants, their parent membranes are mostly lost sight of by being expanded to extreme tenuity, since the cells here usually increase very much in size after their first formation. In woody tissues, formed from cambium-cells, they are mostly so thin as to be almost im-

perceptible; but it appears as though in some instances they became transformed into a kind of cement, gluing the cells together, but capable of being dissolved by nitric acid so as to set the wood-cells free.

Cell-division occurs as a forerunner of free-cell formation in many cases, when a tissue is about to give birth to a great number of free cells; as in the formation of the pollen-grains in anthers, and the spores in the sporanges of the higher Cryptogamia, where the structure is in the first instance developed into a quantity of chambers by cell-division, each of the compartments then producing a free cell.

This must be borne in mind presently, when we come to speak of the modifications of free-cell formation.

Changes in the Nucleus.—During the division of the protoplasm as above described, and in intimate connexion with it, complex changes occur in the nucleus, which have been specially studied by Strasburger in *Spirogyra*. At the commencement of cell-division (*which occurs only at night*) the nucleus increases in size, loses its nucleolus, alters in form, and shows in the centre a transverse constriction in the form of a band, the *nucleus-band*, which is marked by rod-like condensations of protoplasm. Subsequently the nucleus, still increasing in size, again alters its form, becoming barrel-shaped, with an aggregation of granular protoplasm at each end. Division takes place across the nucleus-band in about 15 minutes after its first appearance. Two new nuclei are formed, which separate partially one from the other, but are connected by means of protoplasmic threads with the aggregations of protoplasm at the two ends of the parent nucleus. Other threads gradually connect the new nuclei with the protoplasm lining the walls of the cells, and from which the septum is formed. This septum passes between the two nuclei, and divides the original cell into two, each with its nucleus. During the subdivision of the nuclei, nucleoli are formed in them, but these disappear with the exception of one. In *Spirogyra* the chlorophyll is arranged in ribbon-like coils (see fig. 549), and along these coils, when the cell and nucleus subdivision are taking place as just described, currents of protoplasm, carrying starch-grains along with them, may be seen; so that about three quarters of an hour after the first change in the nucleus, a ring of protoplasm is found to extend round the cell, towards which the starch-grains proceed in great numbers. On this ring the first layer of cell-membrane is formed at the expense of the starch-grains. The nucleus which, just prior to division of the cell, is placed near its centre, is placed, after that process is completed, near the side.

Free-cell formation.—The essential character of free-cell formation lies in the circumstance that the protoplasm which produces the primary cellulose wall of the new cell previously becomes sepa-

rated from the wall of the parent cell, so that the new cell is free (or loose) in the cavity of the parent cell.

Modifications of Free-cell Formation.—These are numerous. The simplest case is where the protoplasm, enclosing *the whole contents* of the parent cell, separates all over from the wall of the parent cell, and, while thus free, produces a cellulose membrane over its whole surface, which constitutes the wall of a new cell.

Fig. 594.

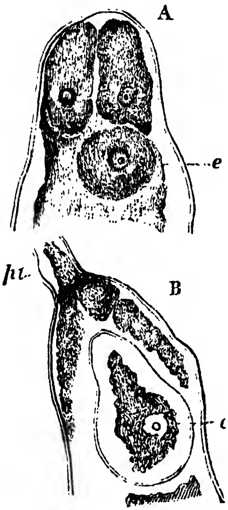
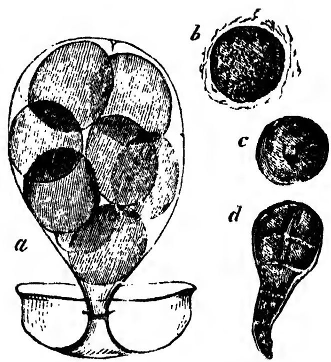


Fig. 595.



Development of the embryonal vesicle of *Santalum album*. A. The upper end of the embryo-sac, with the embryonal corpuscles (*s v*) as yet devoid of cell-membranes. B. The same later, with the pollen-tube (*p t*) adherent: the embryonal vesicle (*e v*) has acquired a cellulose coat. Magn. 400 diam.

Development and fertilization of spores of *Fucus vesiculosus*; *a*, inner spore-sac bursting from the outer sac and about to liberate the spores; *b*, a free spore (devoid of cellulose coat) surrounded by spermatozoids; *c*, impregnated spore with a cellulose coat; *d*, the same germinating. Magn. 160 diam.

This takes place in the formation of the parent cells of the pollen, in the cells of the parenchymatous tissues of the central region of the anther, and sometimes, but not always, in the formation of the pollen-grains. It appears to occur also in the formation of the parent cells of the spores of Mosses, Hepaticæ, Ferns, &c. If the separated protoplasm escape and assume an independent career, the formation is by *isolation* or segregation, as before explained.

A case closely analogous to this is where *the whole contents* of the parent cell become parted into four or more portions, collectively filling the parent cell, but free from it, so that when they secrete their membranes

they become so many free cells, which escape by the bursting or solution of the parent cell.

This case occurs frequently, with the production of four cells, in the development of pollen-grains and the spores of the higher Cryptogamia. Sometimes there is a certain irregularity in such cases, the parent cell either becoming really chambered by cell-division, and forming one cell in each of the four chambers, or at once giving birth to the four free daughter cells.

Other instances of this modification are found in the development of the spores of the asci of Lichens and Mosses, apparently also in the tetraspores of Florideæ. The development in this way of new cells which escape from the parent cell as naked utricles is observed in the spores of Fucus (fig. 595), and in the zoospores of many Confervoids, which are formed in fours in each cell (*Ulva*, *Coleochæte*, &c.).

The resolution of the whole contents of a cell into a great number of free cells occurs in the formation of the very numerous zoospores of *Cladophora* (fig. 512, C, *d*) and *Achlya*, with the formation of the new cell-membrane after their escape from the cavity of the parent; and what is observed in these cases leads to the conclusion that a similar mode of development, going on to the completion of the cells within the parent, occurs in the formation of the parent cells of the spermatozoids or antheridia of the higher Cryptogamia, where a great number of minute free cells are developed, and are found free in the cavity of a large parent cell. The formation of the new fronds of *Hydrodictyon* is a remarkable case of the resolution of the whole contents of a cell into a vast number of free cells, which acquire their cellulose coats and cohere into a new network within the parent cell.

In the formation of the germinal vesicles in the embryo-sac of the Phanerogamia, and probably in the cell corresponding to the embryo-sac in the archegonia of the higher Cryptogamia, *a portion only of the protoplasmic substance* of the parent cell takes part, becoming isolated in the form of one or more (usually three in Phanerogamia) globules (fig. 594, A), one (or sometimes two) of which acquires a cellulose membrane and forms the first cell of the embryo, or its suspensor (fig. 594, B). The new cell is here often very much smaller than the parent cell; and this case thus offers the clearest and most striking instance of free-cell formation.

In the embryo-sac of many of the Phanerogamia we observe, subsequently to impregnation, a process of free-cell formation of a peculiar kind, the protoplasm of the embryo-sac breaking up by degrees into numerous corpuscles, which successively form cellulose coats, and apply themselves to the wall of the embryo-sac, until the layers meet in the centre, and the whole sac is filled up with a parenchymatous tissue, the cells of which (*endosperm-cells*) are at first very loosely coherent. Perhaps the parent cells of the spermatozoids are formed in this way, in the cells of the antheridia of the higher Cryptogamia.

The formation of the active zoospore of *Vaucheria* is really a result of the isolation and individualization of a *portion* of the contents of the parent cell, since here the whole plant is one gigantic cell; but this case is quite different from the developments included in the preceding paragraph.

Free-cell formation occurs either with or without the presence of a

nucleus. If a nucleus be originally present, it disappears, or becomes as it were liquefied in a mass of protoplasm which, from the admixture of cell-sap, becomes frothy below, the upper portion becoming condensed and granular. Around certain portions a cell-wall is formed as just explained. Other portions of the protoplasm become liquid, forming the so-called *vacuoles.*

Development of vessels, epidermis, &c.—The different forms of vascular tissue, including the laticiferous vessels, originate from cells. The most usual course is for a number of more or less oblong cells to range themselves end to end in longitudinal series; after a time the partitions between the cells are broken down or reabsorbed, and a continuous tube results. The immediate inducing cause, and the precise manner in which the partitions are absorbed, are not known.

The *epidermal* cells are in the first instance usually smaller than the other parenchymatous cells, and more closely packed together. They are at first spherical, or nearly so, but shortly assume the usual flattened character. The epidermis is at first destitute of stomata; but these organs are gradually developed in the manner described in the following paragraph.

Development of Stomata.—In certain of the cells the nucleus previously in contact with the cell-well becomes detached from it, and subdivides into two nucleoli; the parent cell-wall then forms a septum between them; and thus two cells are formed in apposition, the septum being at first single, but subsequently splitting so as to separate the two daughter cells and leave an opening (*stoma*) between them which communicates with a wide intercellular space beneath. Sometimes cell-division occurs in the above manner, without the appearance of any nucleus; but the parent and daughter cells, unlike the other epidermal cells, always contain chlorophyll. The intercellular canals, and canals for secretion, originate in a similar manner to the stomata.

Sect. 2. Development of the Seedling Plant.

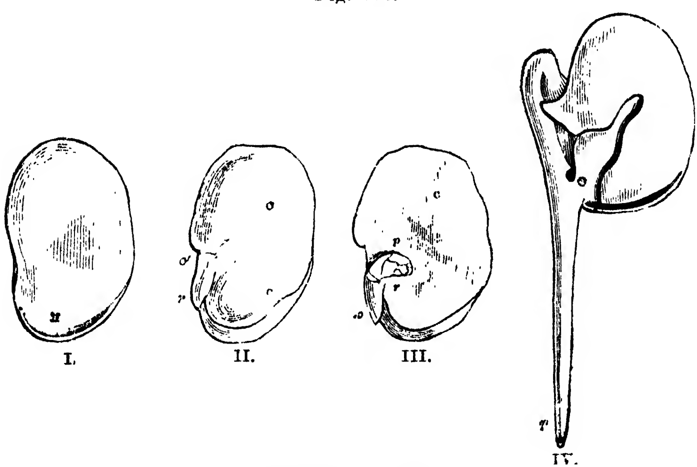
The formation and mode of development of the embryo in Phanerogamia will be hereafter alluded to. In this place it may be well to allude briefly to the principal phenomena witnessed in the germination of the embryo-plant.

Germination of Dicotyledons.—The germination of the embryo, considered in its morphological aspect, begins by the protrusion of the *radicle* (p. 156) in a downward direction, subject to very few exceptions. The structure and formation of the growing point has already been alluded to. After the radicle has protruded, or

simultaneously with it, the two seed-leaves or *cotyledons* (p. 156) gradually emerge from the seed-coats, being raised by the growth upwards of the *tigellum*, or hypocotyledonary axis (fig. 596). If the seed-leaves are thin and leafy they are pushed up above ground, and become *epigeal*, fulfilling at once the functions of true leaves. If they are thick and fleshy, they generally remain beneath the soil (*hypogeal*), or, at any rate, do not perform the functions of leaves but only of store-houses (fig. 596). Between the two cotyledons, at the summit of the tigellum, may be seen the plumule or rudimentary bud enclosing the *growing point* by means of which the stem elongates. Axillary buds, each with its growing point, are sometimes produced in the axils of the cotyledons.

The general process of germination in Dicotyledons is subject to various modifications, such as the union of the two cotyledons in *Anemone*, *Aconitum*, &c., the growing point then making its way through a slit or aperture in the stalks of the cotyledons, which latter, in such cases, often remain within the seed. In *Cyclamen* there is but a single cotyledon, while in other cases no trace at all of cotyledons is visible, the embryo consisting then of a thick tigellum, one end of which tapers ino a radicle, the other forms a stem as in some Myrtaceæ and Clusiaceæ.

Fig. 596.



Germination of the Bean.

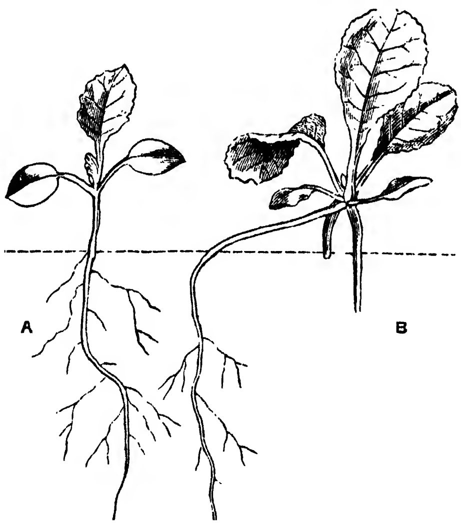
I. Seed; the black mark at the lower end is the hilum.
II. Outer surface of embryo, the seed-coat removed. *c*, cotyledon, *r*, radicle.
III. Cotyledon separated from its fellow and seen from within. *p*, plumule; *r*, radicle.
IV. Shows protrusion of radicle and plumule; the cotyledons still partly enclosed within the seed.

The development of the so-called premorse root and the formation of

the so-called tufted stem are illustrated by the germination of the Cowslip as observed by Mr. Holland. The seedling (fig. 597, A) germinates in the usual way; but, after a time, the weight of the rapidly-growing plumule causes the tigellum to bend downwards and become more or less horizontal. Adventitious roots are then thrown out from the top of the original tigellum, which gradually decays away, and the seedling stage is completed.

The size and appearance of the tigellum vary very much: sometimes it constitutes nearly the whole of the embryo; at other times it is at first relatively small, but is afterwards dilated into tuberous rootstocks and similar formations.

Fig. 597.

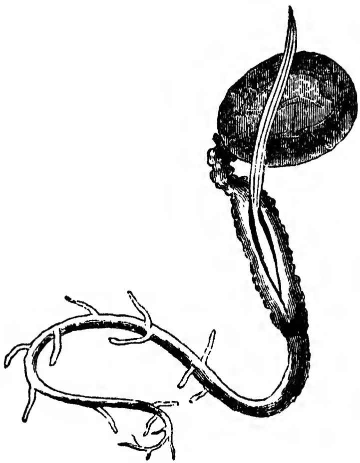


Germination of Cowslip A. First stage with radicle, tigellum, two leafy stalked cotyledons, and plumule. B. Second stage. (*See* text.)

Monocotyledonous Germination.—The radicle protrudes through a *coleorhiza* or root-sheath. Usually it speedily ceases to grow, its place and functions being assumed by numerous secondary or adventitious roots, which also burst through a root-sheath, whence Monocotyledons are sometimes called *endorhizal*, in contradistinction to Dicotyledons, which are *exorhizal*. Some of the latter plants, however, e.g. *Tropæolum*, have a distinct root-sheath. The single cotyledon is either applied to the side of the perisperm in the form of a shield-like body, as in most Grasses, or it is enclosed within

the perisperm, as in most Palms, the Onion, &c. In the latter case the plumule bursts through a slit in the side of the stalk of the cotyledon, which is protruded from the perisperm. In Orchids and some other plants the embryo is at first a homogeneous body without differentiation of parts. The corm of *Arum italicum* is formed from a dilatation of the tigellum. In this plant the radicle is first protruded as a temporary tap-root, then the long tubular sheath of the cotyledon appears, the blade of the cotyledon being of globular form and retained within the perisperm, as in many other Monocotyledons. At the base of the sheath of the cotyledon may be seen the plumule and the originally small tigellum, which latter gradually dilates into a corm.

Fig. 598.



Germination of Palm. The plumule is seen emerging from the sheath of the cotyledon, the blade of the latter being enclosed within the seed.

Sect. 3. Development of the Stem, etc.

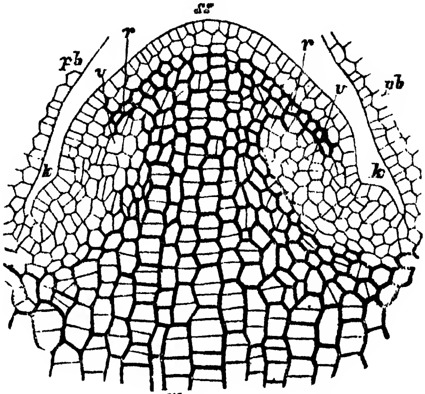
The general structure, arrangement, and mode of development of the fibro-vascular bundles of the stem, roots, and leaves has been alluded to in previous paragraphs, but in this place it remains to give a general indication of the mode of growth and development of the organs as a whole; and for this purpose reference may be briefly made to the *growing-points*, or *puncta vegetationis*, by means of which the growth in length is carried on.

Growing-points.—In the case of Phanerogamia these growing-points are situated at either end of the seedling plant, that in which the direction of growth is upward forming the stem (fig. 599), that in which the direction is downward forming the root (fig. 583, p. 536). The lateral branches originate in similar growing-points, which constitute the essential part of the *buds*.

The buds, in the first instance, are little conical eminences, consisting exclusively of cellular tissue, the constituent cells of which speedily range themselves in three divisions, which may be termed central (plerome), cortical (periblem), and epidermal series (dermatogen): p. 515. Of these the central series form the mass of the young bud; its cells divide at first

in all directions, but subsequently in linear series; the epidermal cells divide by horizontal and parallel subdivisions; the cells of the intermediate cortical series, in the first instance, grow more after the fashion of the central cells. When leaves or branches commence to be formed, the outer cells of the central mass divide by longitudinal partitions at the same time that the central mass itself exchanges its conical for a cylindrical form, ultimately constituting the medulla or pith.

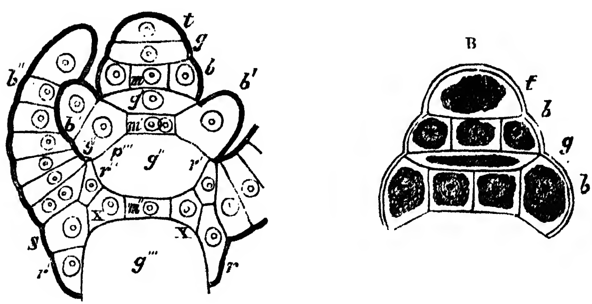
Fig. 599.



Growing-point of *Phaseolus* (after Sachs).
ss, growing-point; *pb*, portions of the first two leaves; *k*, *k*, axillary buds.

The form and position of these growing-points depend materially upon the form of the primordial cells, and on the direction (longitudinal, transverse, or oblique) of their partitions. The form and mode of branching of the stem depend also, in a great degree, upon the position and arrangement of the buds.

Fig. 600.



A, growing-point of *Chara* (after Sachs): *t*, terminal cell, from which are formed *a* and *b*, which latter cells (nodal cells) are divided longitudinally, *m*. Below this is another single cell (*g*) called an internodal cell. This is followed by *m m*, nodal cells. Each cell is nucleated. The internodal cells (*g*) increase in length, but do not divide. The nodal cells divide so as ultimately to envelop the internodal cells. From A the cell-contents have been removed; in B the protoplasmic and chlorophyll granules are seen.

Misled by certain appearances well calculated to produce a false impression, botanists at one time attributed the formation of woody matters in

root and stem to a progressive downward growth: thus the new cells were supposed to be formed from above downwards. It is not necessary to state the argument on which this theory was based, as it has been completely set aside by the researches of Trécul and others, which show that the new tissues are formed at the spot where they are seen, and are not formed from above downwards. Both bark and wood cooperate in the formation of new wood; and either of them may form woody or cortical tissues without the intervention of the other.

There is reason to believe that the growth of the stem of trees takes place principally in the summer months, often in a few weeks, and that comparatively little increase takes place either in spring or in autumn, though in the latter period the new growths are consolidated.

Growing-points of Cryptogamia.—Cryptogams frequently, but not universally, differ from Phanerogams, in addition to other matters elsewhere referred to, in the circumstance that their growing-point terminates in a single *apical cell* (fig. 600), from the repeated subdivision of which in various directions the stems, roots, and their subdivisions originate. No such solitary apical cell is met with in Phanerogams, but a group of cells, as just alluded to.

Sect. 4. Development and Growth of the Root.

The general structure of the roots has been previously mentioned (p. 534). It is, however, requisite in this place to allude to the course of development as seen at the growing-points, which has been made the subject of investigation by Nägeli, Leitgeb, Hanstein, Reinke, and others, especially Janczewski.

In *Vascular Cryptogams* the growing-point of the root is marked by a single apical cell, which undergoes division in two different directions, obliquely and transversely. The new cells formed by oblique segmentation go to make up the body of the root, while the cells formed by transverse division go to constitute the root-cap. The terminal cell of the root (as of the stem) in Lycopods varies in shape; sometimes it is a three-sided pyramid, sometimes a four-sided pyramid, sometimes it is lenticular. The direction of ramification of the roots of these plants (also the phyllotaxis of the leaves in the case of the stem) is intimately associated with the form and mode of subdivision of the apical cell. The elongation of the body of the root is described by Nägeli and Leitgeb as due to successive divisions of the terminal cell in a spiral direction, the direction of the spiral being usually dextrorse and homodromous.

In Phanerogams there is no single apical cell, but a group of cells of the same relative age and order. Janczewski arranges roots, considered with reference to the growth of their growing-point, under five heads:—1. The growing-point is made up of four primarily independent tissues, the root-cap, the epiderm, the cortex, and the central cylinder: the roots of *Hydrocharis Morsus Ranæ* (Frogbit) and of *Pistia Stratiotes* belong to this type. 2. The growing-point is destitute of epiderm, the outer layer of the cortex answering the purpose: the roots of the Onion and of many other Monocotyledons afford examples of this type. 3. The

growing-point is also destitute of epiderm, but its place is supplied by a layer produced from the same tissue as that from which the root-cap is formed: this form is common among Dicotyledons. 4. The primary tissues are not distinctly defined, except along a transverse layer of growing cells or generating layer: this type is also met with in Dicotyledons (Leguminosæ, Cucurbitaceæ), &c. 5. The root consists of two tissues only, the central cylinder and the cortex, which latter fulfils the office of the root-cap: to this last type belong the roots of Gymnosperms; the root-cap as a primary tissue has no existence in these plants.

Root-cap.—The root-cap is formed from a layer of tissue distinct from that constituting the body of the root (p. 536, fig. 583). It grows (except in the first type) by means of a generating layer, which is cast off when its functions are completed, with the rest of the dead portions of the root-cap, as in the second type, or is immediately transformed into epidermis, as in the third and fourth types. In Gymnosperms, as has been already stated, the true root-cap, as an independent tissue, does not exist (fifth type). In Vascular Cryptogams the new layers of the root-cap are derived from the transverse division of the solitary terminal cell.

Epidermis.—This is generally indistinct, and may be altogether wanting, as in Gymnosperms. It is rarely independent (first type). It arises from the transformation of the outer cortical layer (second and fifth types), or from the transformation of the generating layer, as in the third and fourth types.

In the Vascular Cryptogams, the epidermis becomes differentiated after the central cylinder, and does not divide into different layers, except in the case of some Ferns.

The Primary Cortex is a tissue always distinctly separated from the central cylinder. It consists at the apex of the root of a single layer made up of a very small number of cells. Further from the apex the cells divide and subdivide, so that several layers are there formed, generally in a centripetal direction.

The Outer Cortex of collenchymatous cells is always a secondary formation, either from the outer portion of the primary cortex (*Hydrocharis*), or it results from the development of the cells beneath the epidermis in a centrifugal manner (*Stratiotes*).

In the fifth type the cortex is thicker at the apex than at the periphery of the root; in the fourth type it is derived from a transverse generating zone; so that the mode of growth of these two types is quite different from what it is in the three preceding ones.

In *Vascular Cryptogams* the zone from which the cortex originates divides into two layers; the outer forms the outer cortex by repeated subdivision in a centrifugal direction, while the inner layer consists of cells developed centripetally. Intercellular spaces only occur between the cells of the inner layer of the cortex, and not between those of the outer layer. The root of Vascular Cryptogams resembles that of *Stratiotes* in its two cortical layers.

The Central Cylinder is composed in the three first types of an axile vascular bundle and a peripheral zone. In the two last types the cylinder is homogeneous at the summit. The *pericambium* is always early distinctly defined, and consists generally of a single, rarely of two or more layers of cells. While, then, the growth of the root of Vascular Crypto-

gams, by means of a single terminal cell only, is quite different from that of Phanerogams, yet the subsequent development of the tissues takes place in much the same way.

Development of Rootlets.—This takes place in various manners, and has not yet been thoroughly worked out. In all cases the central cylinder of the rootlet arises from the pericambium of the parent root. The root-cap is derived from the internal cortical or protecting layer of the parent root. In Gymnosperms the pericambium is developed into the central cylinder and the cortex of the rootlet, while in Papilionaceæ and Cucurbitaceæ it forms the central cylinder only. In *Vascular Cryptogams* the terminal cell always originates in the inner cortical layer of the parent root, and the pericambium does not play so important a part in the development of the tissues as in the case of Flowering plants.

Adventitious Roots usually, but not universally, occur in places where the atmosphere is warm, stagnant, and loaded with moisture. If a ring-shaped piece of bark be taken from the stem, roots are formed from above the wound, but not from below—a circumstance supposed to be due to the accumulation of organizable matter above the wound; but by others it is considered to be owing to the absence of oxygen. Portions of willow-stems decorticated as above described and grown in water will produce roots below the incision if exposed to the light, and none above the water; and by covering the glass with black paper, and thus preventing the access of light, M. Böhm has succeeded in reversing the phenomenon. The portions of the stem in the water have been found by experiment to give out oxygen under the influence of light.

Direction of Growth.—The downward direction of growth of the roots, as contrasted with the generally upward growth of the stem and its subdivisions, is one of the most remarkable phenomena of plant-life. In the case of the root, one principal reason for the downward growth is the greater amount of moisture received from that side. The root grows by development just within the apex; and the multiplication of the cells in that situation is dependent on a free supply of moisture. The instances of roots of trees growing in the direction of watercourses or drains illustrate this; and when plants are grown in close glass cases their roots are sometimes seen to rise above ground when the confined atmosphere is very moist. We have more than once observed the roots of bulbous plants, growing in water or in damp sand, coil themselves in spirals. Other assigned reasons are dependent on the circumstance that the soft yielding extremity of the young root penetrates the interstices of the soil, and is pushed down by the dilatation and expansion of the older portions above. The downward direction of the root-hairs, when present, would also facilitate downward growth, and prevent the root from being pushed up.

The action of gravitation has also been considered to have some influence over the downward growth by causing the sap to accumulate in the lower parts of the plant, and also the varying degrees of turgescence manifested by the tissues in the different regions of the stem and of the root respectively, pith, rind, &c., such tension being directly dependent on the activity of the nutritive processes in the growing tissues. The direction of growth depends, according to Kraus, on the circumstance whether this turgescence be uniform or unequal or more in one place than another. The combined action of the causes just mentioned is supposed to account for

the varying direction and curvature of the organs of plants; but this explanation does not appear to be wholly satisfactory. The subject will be further considered in subsequent paragraphs devoted to the effects of gravity, geotropism, &c.

Sect. 5. Development and Growth of Leaf-organs.

Phyllomes (and all their metamorphosed forms, such as the parts of the flowers &c.) originate laterally just beneath the absolute apex of the stem, by cell-division of a single cell in Vascular Cryptogams, of a group of cells in Phanerogams—which results in the deflection to one side of a small group of cells forming a conical papilla, or the formation of an annular collar (sheathing-leaves), which develops into an independent lateral organ. These leaves arise *indefinitely*, or acropetally, the topmost being the youngest, in order regulated by the laws of Phyllotaxy. The papillæ from which leaves originate are at first wholly cellular, consisting of periblem covered by a layer of dermatogen cells; after a time elongated cells are formed in the centre; and these are followed by spiral vessels formed in a direction from the base upwards. As a rule, the first part of the leaf formed is its point, which is gradually pushed out by development at the point of junction of stem and leaf. The apical growth of the leaf is generally soon arrested, but interstitial multiplication also occurs in different parts of the leaf (especially in stalked leaves).

The pushing-out of the leaf by development at its base may be well observed in the leaves of Hyacinth-bulbs developed in early spring. Not only are the tissues (epidermis, &c.) younger below, but the relative growth of the parts may be demonstrated by making a series of marks at equal distances up the leaf and watching the proportionate extent to which they become separated. The same process gives very instructive results when applied to the measurement of the growth of the roots of the same plants, and is easily carried out with bulbs grown in glasses of water.

The basilar or *basipetal* mode of leaf-formation above described is that which is most frequent; but in some instances the apex of the leaf, instead of early losing its power of growth, continues to grow and develop new cells in that situation, the cells at the base of the leaf, in these cases, being the oldest. This mode of leaf-formation is called *basifugal.*

These modes of leaf-formation may be well seen in the case of lobed or compound leaves. Thus in the Rose or Passion-flower the terminal leaflet is first formed, and the lateral leaflets afterwards from above downwards, according to the basipetal plan. In *Mahonia* and in many Leguminosæ, such as the Garden Pea, the lower leaflets are formed first and the others subsequently, according to the basifugal plan. The lobes or notches of simple leaves are in like manner formed in one or the other of the methods just alluded to. The stipules are often developed before the leaf-blade; when otherwise, they are probably lateral developments from the petiole rather than separate organs.

Sometimes the two modes of leaf-formation above described coexist in the same leaf; that is to say, the lobes of a leaf may be formed from above downwards, while the nerve passing into each of them gives off its branches from below upwards.

The opposition, alternation, or spiral arrangement of organs depends on the period at which they are developed: thus, if two or more leaf-organs be developed at the same time and in equal degree, a whorl is produced; if the development be *successive*, not *simultaneous*, the organs are then arranged alternately or spirally.

Development of the Parts of the Flower.—The evolution of the parts of the flower takes place after the same general fashion as that just mentioned in the case of leaf-organs in general. The causes producing irregularity and deviations from the typical floral symmetry have been already alluded to (p. 91). It should, however, be remembered that those irregularities are often congenital, *i. e.* exist from the very beginning: in other cases, the symmetry is perfect at first, but becomes subsequently irregular. The congenital arrangement not only shows the earliest stage of the individual flower, but it gives an indication of the ancestral condition. A flower becoming irregular in course of growth, suggests that the primitive type from which the flower in question has descended was regular, the irregularity accruing from adaptation to particular conditions during growth or to special requirements.

Calyx.—If the sepals are indefinite they originate spirally; if definite they are either equal or unequal in number. If equal, the members of each pair originate simultaneously, the lowermost pair first. In a pentamerous calyx, developed on the $\frac{2}{5}$ plan, it is assumed by Payer that one part of an originally quaternary flower is divided into two. Thus, if there are two bracteoles, as previously explained, and two pairs of decussating sepals, the anterior sepal of the lower pair (see p. 89) becomes divided, and one of the two subdivisions is lower than the undivided posterior sepal. This lowest sepal is No. 1; the other subdivision is placed a little higher than the posterior sepal, and is No. 3; the posterior undivided sepal of the lowermost pair is thus placed between 1 and 3, and is therefore No. 2. The two sepals of the upper pair are 4 and 5 respectively. The sepals 1, 2, 3 belong thus to the lower series, 4 and 5 to an upper one. If, however, there are either no bracteoles or two pairs of bracteoles and an originally quaternary calyx, it is the upper pair of sepals which is antero-posterior, as in *Epilobium*. The anterior sepal divides as before, to form Nos. 3 and 5, the posterior sepal being No. 4, and the two lower lateral sepals 1 and 2 respectively. There is, however, no trace of splitting, and it must be assumed to be hypothetical. The development of the $\frac{2}{5}$ arrangement from the formation of internodes between primitively decussate and opposite leaves, as explained by Henslow, seems the more probable explanation (p. 48).

Corolla.—The petals usually originate after the sepals in successive spires, or, much more commonly, in simultaneous whorls. In the case of gamosepalous or gamopetalous flowers, the sepaline or petaline tubercles usually originate free and from above downwards, being afterwards raised from below by the growth of the tube. The tube then, in such cases, does not consist of *coherent* parts, as is sometimes stated, but of parts partially arrested in their development, and consequently not separated. In other cases, especially in the carpellary whorl, the tubular portion is thrust out from the axis prior to the formation of tubercles on its free edge.

Stamens.—These originate either spirally or in whorls, usually from below upwards, or from circumference to centre; if verticillate they always appear simultaneously. According to Payer, the stamens split like the sepals in the $\frac{2}{5}$ arrangement; and this certainly occurs in the case of some polyandrous flowers, e.g. *Polygonum*. Where there are two whorls, generally the outer, but at other times the inner, is developed first.

Compound stamens, or phalanges of stamens, originate as simple tubercles, from the sides of which spring the secondary staminal tubercles from above downwards, as in Mallows. Sometimes one or more lobes or (staminodes) are antherless and petaloid: thus in some cases we have an arrangement like that of an imparipinnate leaf, the terminal lobe petaloid, the lateral ones antheriferous. The whole course of development in such cases precisely resembles that which takes place in the compound leaves of some Passion-flowers or of the Rose.

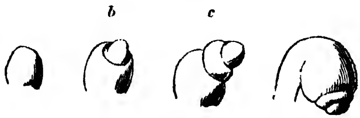
Gynæcium.—The carpels are developed after the stamens from small tubercles, at first free, but afterwards (in syncarpous ovaries) becoming coherent. The original tubercle is more or less spheroid; but as growth goes on, the marginal portions grow more rapidly than the central portion, as in the case of a conduplicate leaf, so that a groove is formed. In due time the margins unite, and thus the cavity of the ovary of an apocarpous pistil is formed; the ovary in a syncarpous pistil is formed by the blending of the margins of adjacent carpels. The styles are formed from the lengthening of the apex of the ovary from below upwards. In the case of *inferior ovaries* the *thalamus*, instead of remaining more or less convex, becomes concave and cup-shaped by the greater proportionate growth at its circumference. The carpels originating from this receptacle become thus more or less completely concealed within, and sometimes adherent to it. In some syncarpous pistils, like the Primrose, the carpels originate as a ring or shallow tube, from whose free border the tubercles, which elongate into the styles and upper part of the carpels, are developed.

Ovules.—The ovule arises from the placenta as a cellular papilla, the nucleus (fig. 601). Around the base of this is formed a ring, which gradually lengthens from the base upward into a tubular sheath or coat of the ovule, *b*. The succeeding coats, which vary in number in different plants, are formed in like manner, are wholly cellular in the first instance, and sometimes permanently. They leave at the apex an unclosed portion or hole, the *micropyle*. During the growth of the coats of the ovule a change in direction usually occurs, so that the ovule becomes inverted.

The true nature of the ovule and its origin are still matters of controversy. Hofmeister considered that they arise like hairs from the epi-

dermis, and are therefore to be regarded as trichomes, while others consider them to originate beneath the epidermal layer like phyllomes. Warming's view is that the ovules originate in the periblem, the derma-

Fig. 601.



Development of ovule: *a*, primary nucleus, invested at *b* by the *primine*, and this by the secundine (*c*); at *d* the ovule has become anatropous.

togen furnishing the coats. The embryo-sac is formed by a cell of the first layer of periblem. The ovules thus originate in the same layer of tissues as do true buds. The coats of the ovule are probably foliar, the nucleus axial.

The structure and mode of development of the pollen and of the ovules will be further alluded to under the head of Physiology of the Reproductive Organs.

Buds.—These are the growing points enveloped by the lateral growths, which, growing faster, eventually cover over the point from which they sprung. Like hairs and leaves, they are exogenous, or formed by lateral outgrowths from a superficial cell or mass of cellular tissue (periblem and dermatogen), and are not, like roots, *endogenous*, or formed in the interior of the tissues.

Adventitious buds, however, are formed, like roots, in an endogenous manner, as also are the shoots of Equisetaceæ. It is requisite, however, not to confound adventitious buds with *latent buds*, which are truly exogenous and normal, save that their development is temporarily or permanently arrested.

According to Warming, the bud and the leaf in whose axil it is placed are organically united, and may be taken as parts of one whole, the two parts being developed to an equal degree, or differently, according to the functions they have to fulfil; one may exist without the other, or both may be present. According to this view, the parent leaf is not a primary stage belonging to the stem, and the axillary bud a secondary phase of growth; but the parent leaf is really the first leaf of the bud itself, and of the same stage or degree of growth as it.

Shoots are only the developed buds. Their mode of ramification has been before alluded to (p. 38). The only point that need be here alluded to is the *ramification by partition*, in which the cells of the growing-point actually divide into two or more groups in a dichotomous or polytomous manner, as in *Hydrocharis*, the tendrils of *Vitis vulpina*, the scorpioid cymes of some Boraginaceæ, Ascle-

piadaceæ, &c. (Warming); but the distinction between lateral bud formation and terminal dichotomy is bridged over by numerous intermediate conditions.

From what has been said on the morphology, structure, and mode of development of the several organs, it will be seen that all the organs of Flowering plants may be reduced to two types—that of the axis (*caulome*) and that of the leaf (*phyllome*), with the hair-like projection from the epidermis (*trichome*). But no arbitrary line, applicable in all cases, can be drawn between these, as they all merge one into the other, or are connected by intermediate gradations. The distinguishing character between stem and leaf least liable to exception consists in the circumstance that a bud may be and is constantly developed at the apex of the stem, while it next to never is at the extremity of the blade of the leaf, though it may be at the end of the petiole.

CHAPTER IV.

GENERAL PHENOMENA CONNECTED WITH GROWTH.

In preceding Sections a general view has been taken of the anatomical appearances and physiological phenomena presented by plants during their growth and development. It will have been seen that the physiological processes alluded to are most intimately associated with, and dependent on, chemical and physical changes, for a full account of which reference must be made to chemical and physical text-books. While the ordinary student has, in most cases, abundant facilities for studying morphology, minute anatomy, and systematic botany, he has rarely the opportunity of studying for himself, otherwise than in books, the details relating to the chemistry and physics of vegetation; and in not one of our schools and colleges is any adequate provision yet afforded for this purpose. The account which can be given here must necessarily be of a very meagre character. The student who wishes to pursue the subject further should read the third and fourth chapters of the third Book of the English edition of Sachs's 'Text-book.'

Effect of External Agencies on Growth, &c.

A plant as a living organism, existing, feeding, breathing, growing, and reproducing itself, is necessarily dependent on many conditions, such as exposure to the atmosphere, access to light, to food, &c. It is under the influence of light, of heat, of electrical currents, of gravitation, &c. And these agencies do not exert their influence singly, but in combination. The effect of the one is modified by that of the others. The living plant is never entirely

in equilibrium throughout its whole structure. The action of one force producing results in one direction is compensated for by the action of other forces producing results in other directions. The general result is a series of compromises of a character necessarily varying according to the relative intensity of this or that action. To disentangle these mixed results, and to ascertain what are the peculiar effects produced by each agency, first separately, and then in conjuction with others, is the task of the physicist, provided with apparatus and instruments of precision.

Effect of Heat.—Vegetable life is not carried on below the freezing-point of water, nor, as a rule, above 50° C., although some seeds and the minute germs of Cryptogams appear to be capable of retaining their vitality under much more elevated temperatures. Each plant, each part of a plant, and each function performed by it, is carried on best and most fully at a certain degree of temperature; it is checked by excess in either direction. The limits within which healthy action and growth take place are necessarily very different in different cases. The germination of seeds, the production of flowers, the ripening of fruits, all the processes of life depend upon the degree of temperature. The successful cultivation of plants in the field, in the garden, in the hothouse depends on the knowledge and practical application of this fact and of the cognate ones derived from a knowledge of the effects of other agencies. Attempts have been made to observe the temperature required for the germination of seeds, the production of leaves, flowers, &c. Thus, for the ripening of Wheat, a certain aggregate amount of heat is required from the period of germination to that of ripening. Other things being equal and within certain limits, it is immaterial whether that heat be received in a shorter or longer period. In southern countries the crops ripen more quickly than in England, in England than in Scotland; but the aggregate amount of heat required is about the same in all cases, though diffused over a longer period in the one case than the other. Vegetation in the extreme north is often effected with great rapidity; for, although the summer is short, the amount of heat is great, and the duration of exposure to light, during the growing period, longer than in more southerly latitudes; hence it is possible to cultivate in the open air in the north of Norway Australian annual plants.

The lowest temperature at which the grains of chlorophyll turn green, according to Sachs, is, for French Beans and Maize between 6° and 15° C.; for *Brassica Napus* above 6° C.; for *Pinus pinea* between 7° and 11° C. The highest temperature at which leaves already formed and still yellow turn green was, according to the same observer, above 33° C. for the first-named plants, and above 36° C. in the case of the Onion.

Exhalation of oxygen and assimilation have been observed by Boussingault, in the case of the Larch, at temperatures only just above the freezing-point. What amount of heat puts a stop to the process has not been ascertained. True respiration or elimination of carbonic dioxide takes place, according to Dehérain, Wolkoff, and Mayer, at a temperature considerably below that which is requisite for growth, being carried on even below the freezing-point, and being manifested in direct proportion to the increase of temperature until a certain maximum is obtained, a maximum exceeding that whereat growth becomes arrested.

Effect of Light.—The effect of light on chlorophyll and the deoxidation which takes place when that substance is exposed to its agency have been already mentioned. But exposure to light is only required for a certain time to allow of the storing up of reserve materials. This latter can be utilized and growth take place in the absence of light. White light is composed of various rays differing, not only in colour, but also in their influence on plants. Most observers, as Daubeny, Hunt, Draper, and Sachs, have considered the luminous (yellow) rays of low refrangibility to be the most potent in affecting the decomposition of carbonic dioxide; but Timiriazeff and Müller assert, from recent experiments with the spectroscope, that the maximum of assimilation coincides with the maximum of heat, not with that of luminous intensity. Carbonic dioxide is decomposed by the rays which are absorbed by the chlorophyll, and of these the most potent are those which have the greatest heating power. This conclusion needs further corroboration before it can displace the generally accepted view.

The highly refrangible rays, blue, violet, &c., "influence the rapidity of growth, alter the movements of the protoplasm, compel swarm-spores to adopt a definite direction to their motion, and change the tension of the tissues of the motile organs" (Sachs, Baranetzky, Pfeffer, Prillieux). The degree of effect produced by light naturally varies, not only with its quality, but also with its intensity. Diffused light, which may be sufficient for the production of chlorophyll, is powerless to induce the further changes which result in the formation of starch. In the case of those seeds (*Convolvulus*, Conifers) in which the embryo, though still enclosed within the opaque coverings of the seed, is found to be green, the chlorophyll must be formed independently of light from the reserve substances in the perisperm. Differences of this character may also be produced by the varying degree to which light penetrates different tissues, and the different modifications to which it is subjected in its passage through tissues of different densities.

Effect of Light, or of its absence, on Growth.—Cell-division may take place either in darkness or in light, provided the requisite materials be at hand. In Algæ, like *Spirogyra*, which have little reserve material assimilation goes on in the daytime, cell-division at night. Hence, as Sachs remarks, in the higher plants assimilation and growth may go on at the same time in different parts of the same organism, while in the simpler organism, where the same cell has to perform both functions, it assimilates by day and divides by night. When a growing shoot is grown in darkness, as in the case of potatoes sprouting in a dark cellar, not only is a blanched condition observable, but also a great elongation. This is also seen in badly lighted hot-houses, or in dark corners of gardens, thick shrubberies, &c., where the plants become "drawn," as the gardeners say. When such shoots are exposed to light the extension of the shoot is arrested and growth in length is retarded, and, as Sachs has shown, a periodical oscillation in the rapidity of growth is caused by the alternation of day and night, when the temperature is nearly constant. The growing internode exhibits a maximum of growth about sunrise, which decreases till about midday, when it reaches its minimum. Contrary to what happens in the stem, the leaves are arrested in their growth in obscurity. Etiolated leaves cease to grow at the point where, under

normal circumstances, they would have begun to feel the effect of the light—that is, at the moment of their emergence from the bud. When the leaf has to shift for itself, starch is formed in those cells exposed to the light first, and all subsequent growth depends upon the formation of that starch. In darkness no starch is formed, and hence, according to Kraus, the arrested development of the growth of the leaf. But Rauwenhoff has shown that the young leaves cannot get all their nutriment for themselves, but must derive some from the reserve stores; if, by means of incisions of the petiole, this be prevented, the growth of the leaf is arrested; and he concludes that the explanation of the arrest of growth in leaves in obscurity cannot be yet given.

The lengthening of the stem in darkness, according to the same observer, depends upon the differences of *tension* between the active pith-cells and those of the fundamental tissue generally and the passive cells of the wood and bark. In normal stems the pith has always a tendency to elongate, a tendency checked by the resistance of the peripheral layers. In darkness, on the other hand, as ascertained also by Rauwenhoff, the bark-cells and wood-cells either are not formed or do not thicken, and hence do not offer any resistance to the growth of the pith-cells.

Reinke has drawn attention to the fact that in previous experiments on plants grown in obscurity sufficient attention has not been paid to the concomitant effect of moisture. He therefore first studied the influence of moisture on the growth of *Helianthus annuus*, taking two seedlings and placing one in the open air, the other under a receiver in fully saturated air. It was found that in the saturated air the growth was quicker than in the ordinary air, yet it fell short of the acceleration which etiolated plants (growing in the dark) had shown. Under the glass vessel in light the stems seemed merely to reach their normal size sooner than in dry air; whereas the darkening caused a quite anomalous extension of the length. This darkening and greater moisture have both an accelerating action on the intensity of growth.

Heliotropism.—Plants exposed to the light bend towards the quarter whence it comes, and become more or less concave towards that side. The side furthest from the light, or, in other words, the darkest side, grows faster than the illuminated side, in accordance with what has been just said. The illuminated side thus resists the growth of the other side, and a curvature is formed, the concavity towards the light, the convexity in the opposite direction. This curvature is called *heliotropism*, and is manifested by plants which have no chlorophyll, as well as by those which possess that substance. Rays of high refrangibility, such as blue or violet, cause heliotropism by retardation of growth. Heliotropism of the kind mentioned is called *positive* to distinguish it from *negative heliotropism*, in which the exact opposite occurs, the illuminated stems becoming convex, as also in the case of root-hairs, some tendrils, the roots of *Chlorophytum*, &c. The kind and degree of curvature are shown by Wolkoff to vary according to the part of the root affected. The same observer also shows that in some instances of negatively heliotropic roots, the translucency of the tissues is such that the rays of light may be refracted, so as to produce a more intense illumination on the side furthest from the light, the concavity of which surface would therefore be a true instance of positive

heliotropism, in spite of appearing to be due to negative heliotropism. But little is yet known as to these points; but it is surmised that there are in plants two sets of cells, some positively heliotropic, retarded in their growth by light, others negatively heliotropic, whose growth is promoted by exposure to the light. Organs in which growth is finished no longer manifest these heliotropic curvatures, of which the greatest degree occurs in the regions where growth is going on most actively. The curves are not produced immediately on exposure to light, but occur gradually, and disappear gradually, even after the exposure ceases. The position and degree of curvature necessarily vary, according to the angle of incidence of the light, and are proportionate to the intensity of the light. Negative heliotropism occurs in the case of the plasmodium or naked masses of protoplasm of *Æthalium* (Myxomycetes). Exposure to light causes, according to Baranetzky, a thinning of the plasmodium, and a corresponding thickening or aggregation in the parts to which the light has no access. As in other plants, the most energetic effect is produced by the blue refrangible rays, the heliotropic effect being not observable in the luminous rays. In darkness, the mass of protoplasm ascends, against gravity, the surface of a wall or other support, but its progress upwards is arrested by exposure to light.

Action of Electricity.—The mechanical and chemical processes which go on in the cells of plants are necessarily connected with disturbances of electrical equilibrium. Ranke, Burdon Sanderson, Velten and others have demonstrated the fact that there exists in plants an electric current such as Du Bois Reymond has demonstrated in the muscles and nerves of animals, but in an inverse direction. While in animal tissues the current is directed from the longitudinal to the transverse section of the muscles, the direction of the current in vegetable fibre is from the transverse to the longitudinal direction. The currents are made visible by the medium of a galvanometer, the epidermis, a bad conductor of electricity, having been removed from the fragment of tissue examined. The electric current in plants, says Velten, has no relation to the degree of concentration of the sap or the state of aggregation of the protoplasm.

According to Ranke, the molecules of a plant are embedded in a connecting substance, and have, according to the direction of the electric current, two positive poles and an equatorial negative zone, just the reverse of what obtains in animal molecules according to Du Bois Reymond.

Plants seem to be regulators of electricity, and restore the balance between the disturbances of the electric tension in the case of the earth and air respectively. Bridgeman has shown (Gardeners' Chronicle, 1873, p. 142) that healthy and luxuriant growth takes place round the negative pole of a galvanic battery, while at the positive pole the direction of the radicles is inverted, and they are thrust *upwards*, grow feebly, and become the prey to mildew.

Velten's recent researches on the influence of electrical currents on protoplasm show that constant and inductive galvanic currents exercise the same effects on the protoplasm and its movements. Very weak electrical currents in parts of plants which offer great resistance cause an acceleration of the movements of the protoplasm, which may be ascribed to the higher temperature brought about by the stream. A very weak

current acting for a long time may result in retarding the movement of the protoplasm, and finally, under certain conditions, in arresting it altogether. Weak currents always produce a retardation of the plasma-movement; and continued for a longer period still, motion may be suspended. After the movement of the protoplasm has been rendered slower, it will again in a short time recover its normal degree of motion, provided it has been disturbed by no sudden fluctuations of the electric current. When the movement of the protoplasm is perfectly stopped, without any other essential change, it after a time gradually sets in again if left to itself. The parts of the cell, in most of the plants examined, in which by electrical effect the protoplasm and chlorophyll granules are accumulated are the septa; but with stronger currents aggregations may appear in various parts of the cell. When once the movement has been checked it only very gradually attains its former rate. By moderate electrical irritation molecular movement is produced. In most cases the different parts of the contents of the cells are unequally affected. Strongly intensified currents deprive the protoplasm of all further power of motion. Very strong currents induce contraction of the primordial utricle. Making a contact has often a greater physiological effect than breaking the contact. The condition of agitation of the protoplasm brought about by the electric current is not transmitted to contiguous parts. By weak currents the protoplasm is enabled to take up water through its imbibing channels; and the water thus taken up may be expressed by the protoplasm itself if left to rest. By moderate, though not too weak, irritation, perfect vacuoles are formed, after which death or resuscitation may follow; this is the boundary of life and death. By strong electrical currents the protoplasm is enabled to take up water in its own interstices: it swells up. The same property is possessed by the granules of chlorophyll. The effect of strong currents is to cause the separation of solid particles of the protoplasm. Protoplasm and granules of chlorophyll are transformed by electricity into the viscid fluid state of aggregation, and separate parts arrived at this state may flow together. The rotation of the granules of chlorophyll in the cells of *Chara* is not disturbed by galvanic currents to the same extent as the protoplasmic movements, and may be viewed even when the movement of the protoplasm has been artificially brought almost to a standstill. Rather strong electric currents in several instances cause a momentary reversion of the circulation; but this is only apparent because it involves some essential changes. On the application of strong electric currents the protoplasm collects with great facility, especially on the cell-wall nearest the one or other pole, in the form of plates or elliptical bodies.

Gravitation, Geotropism.—The effects of gravitation on living plants are ill understood. Knight was the first to show that the downward growth of roots was due to the force exerted by the earth; for when this was removed or supplanted by some force of superior power, downward growth ceased, as when seeds were grown on a rotating wheel, when the roots were directed outward by centrifugal force. Gravitation acts independently of chemical or other forces, and presents many phenomena strictly analogous to those mentioned under the head of Heliotropism. When a plant is so placed that the amount of light is equal on all sides, or when heliotropic curvatures are prevented, gravitation causes some

organs to descend, others to ascend, according as growth is favoured or retarded on the side next to the earth. When growth is retarded on the side next the earth, a curvature, the concavity of which is directed to the earth, ensues, and the extreme growing-point is thus directed downwards, as in the case of the gills of Fungi, and most roots, . Such organs are spoken of as *positively geotropic*, the condition being strictly analogous to positive heliotropism. On the other hand, when growth is accelerated on the side next the earth, the organ becomes so curved as to present its convexity to the earth, and its terminal growing-point is directed upwards, as in the following diagram, where the horizontal line represents the earth, . Such organs as stems &c. are *negatively geotropic*, and are analogous to negatively heliotropic organs. The direction assumed by growing organs depends on the relation between gravitation and tension. If the tension resulting from turgescence is equal on all sides, the root will always grow in a certain direction even against gravity; but if the internal tension of the tissues be greater in one direction than in another, a curvature will result independently of the action of gravity, the under-side of the curved part will grow more freely than the upper end; in consequence, the growing-point will be directed upwards. Kraus remarks, with reference to this subject, that geotropic curvatures, positive or negative, are regulated by the same cause, the more abundant flow of nutritive juice to the lower part of any organ being determined by gravitation, while the direction of the curvature is determined by the degree of turgescence and tension of the tissues. The subject of the inverse direction of roots and stems stands in need, however, of much further elucidation.

Effects of Tension.—These have been already incidentally alluded to; but their influence on the growth of plants may be better understood if it be remembered that the cells are elastic bags subject to be stretched and compressed, with consequent alterations of shape, varying according to circumstances and according as the pressure is from without or from within. Pressure from within, *turgescence*, is regulated by hydrostatic laws; that from without is caused by many varied circumstances connected with growth and the movements of fluid. As the absorption of water is known to be more or less periodic, so also the tension of cells, and the movements consequent on it, are periodic. Organs at first homogeneous as to structure absorb an equal amount of water throughout; but as the structure alters in character at different places, the rate and degree of absorption vary, and the consequent tension also varies in different parts of the plant. Sachs shows that there is an intimate dependence and correlation of growth and tension. Daily periodicity of growth coincides with the daily periodicity of tension; if the former be dependent on changes of temperature and light, the latter is probably so also. One of the simplest of these cases is the separation of the divided portions of a stem when cut lengthwise. Take almost any young growing shoot, preferably one hollow in the interior (the flower-stalk of a Dandelion, for instance), and cut it down lengthwise for a short distance; immediately the separated portions diverge one from the other. The appearance thus presented is like that of the letter **V**; or when, as often happens, the edges roll up, we have an appearance resembling that of the zodiacal sign of Aries, ♈. Again, let the layers of bark and wood-tissue

be carefully dissected off from a young vine-shoot, so as to leave the pith exposed; and it will be seen that, while the bark and wood become contracted (shorten, in other words), the pith lengthens. A similar contraction ensues, but in a transverse direction, when a ring of bark is cut off from a shoot. Try to fit it on to the stem from which it was taken, and it will be found impossible to replace it accurately. Dr. Bird decisively proved that the divergence in question was due to varying degrees of tension, these variations being dependent in his experiments on the alternate emptying of certain cells, and the filling or turgescence of others, and *vice versâ*—the transfer of fluids in this case from cell to cell taking place in accordance with osmosis. Certain of the tissues are erectile, left to themselves they have a tendency to extend in all directions; certain other of the tissues are by comparison passive, and act as a check on the erectile tissues. Speaking generally, the spongy cellular portions, such as the pith and the cellular portions of the bark, are erectile; while the skin or epidermis and the fibrous stringy tissues (wood) are passive. To varying relative conditions of these parts the movements of plants may, in great measure, be attributed. For instance, the divergence which occurs when a Dandelion or other herbaceous stem is cut down, depends on the sudden disturbance of the balance heretofore existing between the erectile central portions and the passive outer portions of the skin: the latter gain the advantage, and curvature results, owing to the adhesion of the cells to the rind; but if, as in Dr. Bird's experiments, the advantage of the central tissues is restored by the imbibition of fluids, the cut surfaces then lose their curvature and become parallel to each other. And so, in regard to our second illustration, the contraction that takes place when a ring of bark is removed from the subjacent cells affords another illustration of the difference in tension of the different elements of the stem.

The tension which occurs in plants is always liable to fluctuations in degree, and may either be permanent or transitory. Permanent tension is that which occurs as a result of unequal growth, while transitory tension is due to variations in the quantity of water absorbed, as in the experiments just alluded to. There is always a tendency to maintain an equilibrium; the tensive forces are, in theory, at least, equally and symmetrically distributed, but this equal distribution is continually being interfered with by variations in the vigour of growth and the amount of light, heat, and moisture to which plants are subjected.

It has been long known that if a growing shoot be shaken several times in succession, a curve will ultimately be formed in it, the centre of which curve corresponds with the place where the tension is at its maximum. The irritation produced by the continued shaking stretches the passive tissues (epidermis) and diminishes their elasticity and consequent power of resistance to the erectile tissues within, which are, in consequence, enabled to grow the more rapidly. If this stretching of the rind be uniform on all sides of the shoot, a simple lengthening will take place; but of, as is usually the case, thestretching be more on one side than the other, then a curve is produced.

Periodic Variations in Tension.—The degree of tension varies, as has been said, at different times of the day and in different parts of plants. Under ordinary circumstances, according to Kraus, the tension diminishes in

early morning, and is at its minimum about 2 P.M., from which time it gradually increases. In annual plants the maximum degree of tension is at the base of the stem, and diminishes towards the end of the branch e and of the roots, where the growth is most active. The effect of increased tension at the base of the stem would force the nutrient fluids in the two directions where it is most required. The greatest tension in young shoots is also at the base, the sap being thus forced towards the growing-point. In the case of bulbous plants the greatest tension is exerted in the stem, so that the nutritive juices may be forced into the bulb.

Periodicity of Growth.—Connected with the growth of plants two separate phenomena are observed: the one a regular onward course of growth from infancy to maturity, varying in degree, rapidity, and duration, according to hereditary endowments, attaining a maximum, and then gradually decreasing; the other a fluctuating, intermittent, or periodic growth. The former is called by Sachs the *grand period of growth.* The rate of increase in the case of the grand period is not directly in connexion with changes of temperature and other outward conditions, but is to some extent independent of them. The rate of growth, moreover, varies in different parts of the same organ, so that there is one portion where a maximum rate of growth is observed. According to Sachs, the maximum rate of growth in stems is greatest at some distance from the apex of the stem, while in roots the fastest growth takes place much nearer to the apex. But this statement appears, from Bennett's researches on *Vallisneria* and the Hyacinth, to be too general. The author last cited found that in the peduncle of *Vallisneria* the rate of growth was much more rapid near the summit, while in the case of the flower-stalk of the Hyacinth the reverse was the case. In *Tritoma* the greatest and most rapid growth was observed to take place near the upper end of the scape. While the grand period of growth, considered as a whole, augments in intensity gradually till it reaches a maximum and then declines, yet, if the growth of internodes, or short intervals, of the stem be measured at frequent intervals, the rate of growth is found to be very irregular, so that if projected in a diagram it would not form a uniform curve, but a series of zigzags. These variations Sachs attributes to differences in temperature and other outward circumstances, and further points out the existence of a direct relation between the rate of growth and the tension of the tissues, the curves representing the two phenomena being identical. Reinke, however, disputes these conclusions and attributes the variations to inherent changes in the plant itself in association with variations in the degree of humidity, &c. &c.

Day and Night Growth.—The evidence as to whether the greatest amount of growth takes place by day or by night is still conflicting, though, from what has been before said as to growth and cell-division, as well as from direct measurements, the balance of evidence goes to show a greater relative growth in the hours of darkness, the maximum being observable just before sunrise, the minimum soon after noon. The conflicting statements arise from the great variations in temperature, light, moisture, &c., so that it is only by eliminating, so far as possible, the effects produced by heat from those which are the result of light, and so on, that a decision can be arrived at; and when such a decision has been obtained, it is

necessarily of relatively little value, since it by no means represents what happens under natural circumstances.

Rauwenhoff, whose paper on this subject is the most complete, and which contains references to the literature of the subject, shows that the day and night growth is variable in different species, that what holds good in one does not do so for another; and this agrees with the result of Lindley's experiments, in the Transactions of the Horticultural Society of London, new ser. vol. iii. p. 101.

Measurement of Rate of Growth.—For purposes where great accuracy is not required, marks made upon the growing stem at regular distances apart, or a measuring-rod placed in juxtaposition, are sufficient; but where great accuracy and the measurement of minute spaces are demanded, recourse must be had to special instruments called *Auxanometers*. In the simplest form of this instrument a thread is attached to the growing plant, the other end of the thread being carried over pulleys and moving an index attached to a scale. Self-registering growth-measurers present many advantages. In these the rate of growth is marked by an index attached by a thread to the plant, and travelling over a blackened cylinder revolving by clockwork in fixed periods of time, and on which the indications of the index are traced.

Alternations of Growth.—In addition to periodic or rhythmic waves of growth, a sort of compensatory growth is often observed; so that if growth be active in one organ, it is relatively passive in another, and *vice versâ*. If one organ be hypertrophied or inordinately developed, it often happens that another is correspondingly restricted. The operation of this law of compensation is particularly evident in many cases of monstrosity. It may also be easily observed in the case of many Conifers, *e. g.* in *Araucaria imbricata* or *Abies Nordmanniana*, where in one season the growth of the terminal shoot exceeds that of the lateral subverticillate ones beneath it, while in another season the lateral shoots grow faster than the terminal one.

Force exerted during Growth.—The force with which fluids ascend in the stem has been repeatedly measured from the time of Hales; but the actual force exerted by the mass of growing tissues has not been so frequently made the subject of accurate measurements. It is common to see stones uplifted by trees in their growth, and paving-stones raised by the growth of Fungi beneath them. Clark has subjected to measurement a growing fruit of a Pumpkin, which from raising weights of 50–60 lb., finished by raising one of 5000 lb., its own weight being 47 lb. The growth of the roots of this plant was estimated at 1000 feet a day. This is no doubt an extreme case, but it may suffice to illustrate the enormous force exerted by plants in their growth.

CHAPTER V.

REPRODUCTION OF PLANTS.

Sect. 1. Vegetative Multiplication.

It is a remarkable characteristic of the Vegetable Kingdom, shared, indeed, by some of the lower animals, such as Sponges, Polypes, &c., that their organizing forces are diffused throughout their structure, whence results, not only great repetition of similar and, to a certain extent, independent parts in the same plant, but a capability in those parts of surviving when separated from the parent stock, and of becoming the foundations of new plants. Through this condition of the organization arises the possibility of a *multiplication* of individual plants by simple subdivision of the vegetative structure of a single specimen—a process which is not only universal throughout the Vegetable Kingdom, but in many cases is so frequently and abundantly manifested as to throw the proper *reproduction* by seeds or spores into the background.

As will be seen hereafter, the spores of some Families are really formed by a kind of vegetative multiplication intermediate between the proper reproductive process and the development of the new plants; but it will be more convenient to examine those cases in connexion with the formation of spores and seeds generally, and to confine our attention here to what are distinctly and evidently bud-structures.

Buds; Gemmæ.—The modes of vegetative multiplication of plants necessarily depend essentially on the organization of the species; accordingly as the vegetative structures present more or less complexity, so are the "buds" more or less developed at the period when they are detached from the parent.

Gemmæ of Thallogens.—In the Thallophyta, where the entire organization is cellular, and no leaf-structures exist, the buds or *gemmæ* are cellular structures, more or less complex, according to the condition of the parent thallus. We have examples of the simplest kind of multiplication in *Schizomycetes* and the lower Algæ, such as *Palmelleæ*, *Desmidieæ*, &c., where the plants are continually undergoing propagation by division of the constituent cells. In some cases no other mode of reproduction is yet known, and such multiplication appears to represent the vegetative growth of higher forms; but in others a true reproduction, with formation of spores, recurs periodically to interrupt the simple cell-division, in a manner analogous to the recurrence of flowering, after a certain extent of vegetative growth, in the higher plants.

In the Fungi many kinds are abundantly propagated by *conidia*, or simple cells detached from the mycelium, as is the case in the growth of Yeast (p. 552), in the propagation of the Vine-fungus, &c.; and in all probability the Fungi generally may be increased by artificial division of the

thallus, as we see it practised in propagating the Mushroom, the Vinegar-plant, &c. In the Lichens there is a proper structure to which the vegetative mutiplication is confined, viz. the *gonidia*, the green cells formed in the medullary layer of the thallus, which frequently break out from the surface and become free, especially when the plants are exposed to excessive damp. These gonidia, however, are now considered to be Algæ, entangled in the meshes of a parasitic fungus.

In the Algæ the vegetative multiplication exhibits very varied characters. In the Confervoids (p. 451) we have the *zoospores* and *swarm-spores* (fig. 512, C, *d*, and fig. 591), as also in the Phæosporeæ: and the *tetraspores* of the Rhodospermeæ and the Dictyotaceæ probably have the same import; but, in addition to this, the thallus is commonly multiplied, especially in the larger forms, by the growth of a number of new thalli from the sides or the base of an old plant, and their subsequent separation by the decay of the parent thallus.

In the above cases we see the double representation of the vegetative process which occurs in so marked a manner in the higher plants. We have increase by simple and pure subdivision of ordinary vegetative structures, and, besides this, we see varied modifications of the vegetative cells specially organized to fit them for being thrown off spontaneously (*gonidia*, &c.).

In the Hepaticæ and Mosses the propagative structures do not arrive at the condition of *buds*, although the parent plants have leafy stems. The *gemmæ* of these Classes are merely cellular nodules, more or less developed in different cases, and only acquire leaves after they have become independent. In the Jungermanniaceæ they are developed on the leaves or in place of fruits. In Marchantiaceæ they are found in cup-like receptacles, being especially frequent when the plants grow in damp, shaded localities, a number of them (springing originally from a single cell) lying in the cup like eggs in a nest.

The Mosses produce *gemmæ* from all parts of their structures—from their leaves, stems, metamorphosed fruit-organs, and, above all, from thread-like runners (*protonema*) which shoot out from the base of their stems. When their spores germinate, they also form first a mesh of confervoid filaments, each joint of which often gives birth to a leaf-bud (fig. 499, p. 430).

Buds of Vascular Cryptogams.—The Ferns and allied Classes agree more closely with the Flowering plants in their vegetative propagation, forming leaf-buds in cases where they increase in this way; but there is a connexion with the Mosses &c. in the circumstance that their *gemmæ* appear more frequently on the leaves than is the case normally in the Phanerogamia—as, for example, in *Asplenium rhizophyllum*, where the leaves root and form buds at their tips, *Cystopteris bulbifera*, in which bulbils appear on the petiole, &c.

Buds of Phanerogams.—In the Phanerogamia the rule is, that every leaf-bud may be separated from the parent stock, and, if properly treated, reared into a new plant; moreover, in a vast number of cases, the leaf-buds are naturally modified in certain details of their structure, so as to protect them from external injury, and then thrown off spontaneously by the parents to multiply the kind. Many of the cases of this phenomenon have been described in the first part of this work under the head of

Morphology of Stems (p. 20 *et seq.*) and Buds (p. 69). We have there spoken also of the formation of *adventitious buds* (p. 70) and cited numerous examples strongly indicating that relative independence of the parts of the organization of plants referred to above.

Adventitious Buds are formed mostly when a plant or part of a plant loaded with assimilated nourishment is deprived of its natural developing-points. Thus we see abundant formation of adventitious buds on healthy trunks of trees which have been *pollarded, i. e.* have had their heads cut down so as to remove almost all their natural buds. Sometimes the shoots so produced simply result from the development of otherwise *dormant buds.* The abundant supply of food existing in the trunk, however, often stimulates the cells of the *cambium-region* (p. 530) into extraordinary development, and true endogenous leaf-buds are produced, which form vents for the vital energy of the plant. This power exists even in the roots of many trees, as in *Maclura aurantiaca, Pyrus japonica,* &c., fragments of which in a healthy condition may be made to produce new plants. The buds so formed are of endogenous origin, arising in or near the cambium-region.

Mention has been made of the formation of adventitious buds (as exogenous formations) on leaves, which has been observed frequently in wild plants, and is artificially induced in many cases as a means of propagation. As a rule, leaves are less prone to produce buds than stems or even roots, as might be expected from the more actively changing state of the contents of their tissues, and the usual absence of any great accumulation of assimilated substance, such as is regularly met with at certain periods in the stem and root.

That striking characteristic of vegetables which displays itself in the physiological independence of the leaf-buds, renders the vegetative propagation of plants a most important feature in their history, both in a natural and, in a still higher degree, in a cultivated condition.

A brief notice of some striking phenomena illustrative of the spontaneous propagation of the higher plants may be given here.

Various herbaceous plants are multiplied by spontaneously detached axillary leaf-buds: of this we have familiar examples in *Lilium bulbiferum, Dentaria bulbifera,* and the cultivated species of *Achimenes.* Similar propagative buds are often produced instead of flowers in the inflorescence of the species of *Allium* (Garlic, &c.), both in a wild and cultivated condition; and the same is the case with some other plants, such as *Polygonum viviparum,* &c.

The multiplication of *bulbs* by "cloves," or axillary bulbs produced in the axils of the scales of the parent bulbs, has been described in a former Chapter (p. 25), and there also have been mentioned the structures called tubers, formed of modified stems, which are important agents in propagating the plants in which they occur. The Potato, for instance, forms tubers from its branches, the "eyes" or buds of which may be separated and made to produce each a new plant: and the Jerusalem Artichoke, Dahlia, &c. are similar in this respect. The terrestrial Orchids, such as *Orchis Morio* (fig. 21) &c., are not *multiplied* by their tubers, but only *continued* from year to year, since only one new "eye" is formed annually.

Still more frequent, perhaps, than the formation of bulbils, bulbs, or tubers is the development of leafy shoots peculiarly organized for the

purpose of propagating the plant which bears them, commonly comprehended under the names of offsets, stolons, runners, &c. Almost every gradation of condition occurs here, between the divisible rhizomes of such plants as the Daisy, Primrose, &c., the "runners" of the Strawberry, *Vallisneria*, *Hydrocharis*, &c., the offsets of House-leeks, *Stratiotes*, and the rosette-like stolons of *Epilobia*, &c., which approach to the axillary bulbils of *Achimenes*, and connect all these forms with the subterraneous bulbs, corms, and tubers.

Propagation by Artificial Means.—The artificial propagation of plants by division is effected by a variety of processes founded on the same physiological laws as the natural multiplication by detached buds, &c.; it also includes a peculiar class of operations, in which the new plants are not converted into absolutely independent stocks, but are made to assume a pseudo-parasitical habit upon other plants, whose roots furnish them with that portion of their nourishment which is derived from the soil.

In the simple propagation, advantage is taken of the vital activity of the cambium-region to stimulate it to the production of roots, in the gardening processes of propagation by *slips* or *cuttings*, *layers*, &c. In the production of pseudo-parasites, as in *budding* and *grafting*, the woody structures of two distinct plants are made to become intimately blended by bringing into immediate contact the cambium-structures of both, at points where the cellular tissue is in an active state of development.

Cuttings or Slips are ordinarily fragments of stems consisting of young wood bearing one or more buds. These are planted in earth, and in some cases require no especial care to make them produce adventitious roots from the cambium-region, as in slips of Willows and many common soft-wooded plants. Mostly, however, it is necessary to stimulate the vegetative action by a slight degree of artificial heat—in all cases, however, guarding against drought; so that, as a general rule, cuttings are made to "strike" root best in an atmosphere where the watery vapour is confined by a glass covering. It is a matter of indifference whether a cutting having a number of "eyes" or buds is planted with the head upward or with the summit buried in the soil and the lower part left free. In the latter case, the ordinary direction of growth of all the new shoots becomes reversed. When a cutting is made, a *callus* of cork-cells is formed over the wound, and the adjacent cells are filled with starch-grains, prior to the formation of the roots.

It has been stated above that by careful management plants may be raised from cuttings of roots, and even from leaves made to produce adventitious buds by artificial stimulus.

Layers only differ from cuttings in the circumstance that the fragments to be detached are made to strike root before they are separated from the parent stock—usually by bending down the branches and burying them in a portion of their course in the soil; an incision is usually made into the wood in the buried portion, which causes the more ready production of adventitious roots. An analogous operation is sometimes practised, in which

a shoot is caused to root high above ground, by surrounding one or more of its nodes with a mass of earth kept moist by wet bandages or other means.

The artificial process of *layering*, practised commonly with Pinks, Verbenas, *Aucuba*, &c., is analogous to the natural propagation of the Strawberry by runners.

In all the cases comprehended in the above remarks, the adventitious roots are formed most readily in the vicinity of buds, at the nodes, just as we see them naturally occurring chiefly in those situations in creeping plants, such as the Sand-Sedge (fig. 25), Mint, many Grasses, &c., which root at every joint that comes into contact with moist soil, or in the climbing Ivy, in which the adventitious roots forming its organs of attachment to foreign bodies are produced in tufts a little below the leaves.

Grafting.—In the operations of *budding* and *grafting*, the parts of the parent plant are caused to assume a kind of parasitical condition, in which they stand in the same relation to a strange "stock" as they would have held to their parent if left in their natural condition. The detached bud or shoot is made to contract an organic union with the cambium-region of a foreign stem, of which it becomes, as it were, a branch, deriving its supplies of root-nourishment from it, and subsequently sending down in return elaborated juices to contribute to the sustenance of its foster parent. It is important to note, however, that in the case of distinct plants thus combined they usually exercise no appreciable influence over each other in regard to modifying the *morphological* characters of each; the connexion merely affects the scion and stock in the degree of activity of the general physiological processes of nutrition, &c. Scions grafted on stocks of more enduring character acquire greater vigour and fecundity; but the products of the buds of the scion, in the great majority of cases, resemble in kind those of their parent, while the stock continues to grow in its own way. The influence of the scion on the stock, is rendered less noticeable in practice from the fact that buds or branches of the stock are always removed after the scion has "taken," in order to concentrate the sap in the latter; and if allowed to develop, the branches of the stock formed below the scion mostly remain unaffected by the stranger which has settled above them.

Influence of Stock on Scion.—A certain amount of physiological influence of the stock over the scion is shown to exist by such facts of horticultural experience as the dwarfing of certain varieties and their earlier or increased productiveness according to the stock, as in the case of Apples on the Paradise stock, the fact that the fruit of the Pear is smaller and more highly coloured when "worked on" the Quince or Medlar than when grafted on Pear-stocks, and is earlier when worked on the Mountain Ash. It is not clear here whether the alteration is attributable to greater or less vigour of the stocks, or to an influence obstructing the return of elaborated sap towards the roots, arising out of difference of texture of the wood.

Influence of Scion on Stock.—On the other hand, the scion has been in a few cases observed to affect the stock. It is well known that the variety of the Yellow Jasmine with variegated leaves, budded on a plant with healthy green leaves, causes the gradual appearance of variegation through-

out the whole of the foliage of the plant. The same phenomenon has been witnessed repeatedly in the case of variegated kinds of *Abutilon*. If a variegated scion of *A. Thomsoni* be placed on a green-leaved stock, the new leaves pushed out from the latter become also variegated. If a green scion be placed on a stock of the variegated *Abutilon*, the new leaves of the scion become variegated. Further, if the variegated scion be removed from the green-leaved stock, the latter no longer produces variegated, but only green leaves. A still more striking phenomenon is the production of a hybrid Laburnum, by grafting *Cystisus purpureus* upon the common Laburnum. Many such cases are now authenticated, and will be referred to under the head of Hybridization.

Budding consists in attaching the bud of one tree upon the developing wood of another. For this purpose the bud is removed from its parent with a slip of the bark surrounding it, bearing on its inside a portion of the cambium-tissue existing at the line of junction of the innermost region of the bark with the youngest wood; this is applied upon the surface of a portion of the cambium-layer of the stock, exposed by slitting its bark and turning it back so as to form a kind of pocket. The slip of bark is inserted into this, so as to bring the cambium of bud and stock into complete contact, and the bark of the stock is then carefully bound down over the wound with bandages of bast, tape, &c. The organizing force resident in the cells of the cambium of the two portions causes them to grow firmly together.

In *Grafting*, a shoot instead of a bud is attached to the stock; and this is commonly effected by cutting off the head of the stock (or a branch of sufficient growth) with an oblique surface, or with a deep notch offering more than one oblique surface; the bottom of the shoot or graft is pared so as to fit accurately on the oblique surfaces, and in this way considerable tracts of the cambium-tissue and young wood are brought into contact—their cells, however, being partly end to end here, instead of side by side as in budding. Union of the growing region takes place exactly as in the former case. Grafting is usually practised with young woody structures; but it is also successfully applied to herbaceous plants with careful management; and some Grasses even admit of being grafted on each other, although the operation is generally confined to Dicotyledonous plants.

What is termed *Inarching*, or "grafting by approach," may be compared to *layering* (p. 617): in this modification of the process, the scion is brought into union with the stock by bending over or otherwise, without being detached from its own stem, and the separation is not made until the scion has "taken" on its foster-parent, &c.

It was at one time imagined that the annual layers of wood of Dicotyledonous stems grew down absolutely and mechanically from the buds, of which they were said to represent the roots. It was thought also that, in the case of grafts, the scions sent down woody structure over the old wood of the stock, so as at length to enclose it. From the description given before of the horizontal development of the cambium-layer of Dicotyledons, it will be seen that such notions are devoid of all ground. Merely fluid matters pass up and down in the cambium and bark, and the only reciprocal influence of stock and scion depends on the respective activities of roots and foliage.

The success of grafting depending on the contraction of intimate union between the cellular structures of the two plants, it is not surprising that, as a rule, it is only between nearly related plants that such union is possible. If the size of the elementary organs, the rapidity or the extent of their periodical multiplication and expansion, &c. are unequal, it is evident that no permanent coherence can exist; a tissue growing more rapidly would tear itself away from one less active. As a general rule, the elementary tissues agree closely in allied species, less closely in genera of the same Order, and are very diverse in different Orders; so we find that grafts take readily on stocks of their own species, to a considerable extent on stocks of allied species, and to some extent on stocks of genera belonging to the same Order. As a general rule, genera of distinct Orders cannot be grafted with success. The parasitic Mistletoe, however, attaches itself by a natural graft to various trees, such as Apples, Oaks, and even to Coniferæ.

Some as yet unexplained exceptions exist to the inclination to union between allied genera. In some cases, also, a temporary union is effected, subsequently destroyed by unequal growth.

Among the Rosaceæ we see Pears grafted readily on Quinces, with more difficulty on Apples, and not at all on Plums or Cherries. Cherries and the Cherry-laurel readily unite. In the Oleaceæ we have the Lilac uniting with the Ash, the Olive with *Phillyrea*. It is extensively practised also with diverse species as well as varieties of *Rhododendron*. The Pear may be grafted on the Hawthorn; but the former grows so much faster than the latter that the communication between the two becomes interrupted in a few years at the point of junction.

The practices of grafting and budding are principally carried on, like propagation by slips &c., for the multiplication of varieties, which are, for the most part, grafted on other varieties, or normal specimens of their own species, these being far more healthy and permanent than those grafted on allied species. The multiplication of esteemed varieties of Roses, fruit-trees, &c. is chiefly effected by this means, the object being to produce specimens promising increased hardiness &c., or to obtain size and fertility earlier than could occur in a plant raised from a small cutting. Moreover, much greater certainty of reproducing the desired form is attained than is the case with seeds. The seeds of an Apple, for instance, rarely reproduce the parent form exactly.

The Peach is worked on the Plum in Britain, because the latter is a native of this climate and is stimulated to growth in spring by a lower temperature than the Peach (from Persia); it does not succeed well here on Almond-stocks. The Pear seems to succeed better on Quince than on Pear-stocks in loamy soils; and many similar instances are well known to gardeners. In addition to these circumstances, Pears, Apples, and other plants which may be easily grafted do not readily root from cuttings; moreover esteemed varieties of Rose &c. are quickly multiplied as "standards" &c. by budding them on briar-stocks already of several years' growth; and, in the case of new seedlings of fruit-trees, buds inserted on full-grown stocks are brought to flower and fruit in a few years, while if left to grow up into trees alone, twenty years or more might elapse before they bore a crop.

Certain phenomena of grafting which are observed in practice cannot

be fully explained by our present knowledge, but doubtless depend on causes similar to those just adverted to; among these are the facts that the Orange succeeds better on a Lemon-stock than on one of its own species, while the Apricot does better on its own species than on the Plum, &c. The influence of the physiological conditions of the stock upon the scion is turned to account by gardeners in producing a dwarfer "habit" and an earlier and more profuse production of fruit. Thus Apples grafted on the low-growing "Paradise stock" assume the dwarf habit of the stock and become more prolific. So Pears on the Quince-stock not only are dwarfed in size, but produce fruit much more abundantly than when grown on their own roots or grafted on another kind of Pear. Gardeners often practise "ennobling" fruit-trees, where buds and grafts are attached upon stocks of good varieties of the plant in preference to wild stocks. Thus Apples are said to be much superior when grafted on stocks of good varieties instead of on Crabs, &c.; and a kind of crossing of the qualities of varieties has been attempted on this principle, grafting kinds which bear sickly-flavoured Apples upon stocks of rougher varieties, Jargonelle and "mellow" Pears upon later, gritty varieties, &c. "Double grafting" is done when it is desired to secure a particular kind of fruit which will not unite or graft with the ordinary stock; thus a Pear may be grafted on a Quince-stock, and on the scion may be grafted another Pear, which will not unite directly with the Quince. Further details on the subject of grafting, a most important and interesting one, must be sought in horticultural works.

Sect. 2. Sexual Reproduction.

Preliminary Observations.—In almost all plants the greater part of the active existence is passed in the development of vegetative organs, increasing the bulk of the individual, or occasionally also accompanied by multiplication of the plant by mere subdivision into parts. But at certain epochs another tendency manifests itself: the energies of the plant become concentrated in the formation of what are called reproductive organs, for the purpose of producing and maturing those independent germs of new individuals of the species called *spores* and *seeds*.

The formation of reproductive structures bears a very interesting relation to the vegetative development. Generally speaking, the reproductive organs are only formed when the vegetative structures have become healthily developed, so as to accumulate a certain amount of assimilated matter in the substance of the plant. We observe that many garden plants grown in unfavourable soil, in shady localities, &c. will not flower; and the number of years that elapse before the flowering of such plants as the Agave, Talipot Palm, &c., varies with the more or less favourable climate and soil; moreover, in ordinary cases, the flowering takes place at the close of the season of growth (except where the flowers emerge from buds provided for by the previous year's vegetation, as in Apples &c., in biennial and many perennial herbs). This indicates that vigour of the vegetative organs is a necessary condition of reproduction.

Further, reproduction is an exhausting process; it kills some animals: and excessive fruiting exhausts perennial plants.

At the same time, the reproductive tendency and the vegetative tendency appear contrasted and opposed to each other; for reproduction is often retarded and replaced by rapid development of vegetative structures when plants are placed in too favourable a soil, especially when too freely supplied with water; and rankly growing plants are frequently made to flower by gardeners cutting the roots, confining them to small pots, or limiting the supply of water.

The reproductive bodies produced by plants are either developed at certain epochs from structures originally belonging to the vegetative system, or they are formed in special organs. In the lower Algæ we find the cells, as those of the filaments of *Œdogonium* (fig. 505) or *Spirogyra* (fig. 512), originally true vegetative cells, and at a certain stage of growth resolved into reproductive cells and producing *spores* from their green contents. As we rise in the scale, among the Thallophytes, we soon find special cells (*Penicillium*, &c., fig. 1, C) or groups of cells, exclusively vegetative or exclusively reproductive. In the higher Cryptogams, assemblages of organs of various kinds are formed upon the stems, in which are ultimately ripened the *spores* of this group; while in the highest class, the Phanerogamia, we meet with flowers containing stamens and pistils, ultimately producing true *seeds* in fruits which are totally separated in almost every case from the vegetative structures.

The spores of the higher Cryptograms (Ferns, Mosses, &c.) cannot be properly compared to the seeds of the Flowering plants (that is, morphologically), since they result from a series of physiological processes different in many respects and not directly dependent on sexual agency. With regard to the spores of the Thallophytes, our knowledge is too imperfect at present to enable us to decide in all cases upon all the homologies; the probable relations of the different kinds of structure are incidentally spoken of in the Sections devoted to the description of these plants.

It is probable that representatives of two sexes, male and female, exist in all plants, and that these conjoin to form the rudiments of the new individuals of all Cryptogams, as they do in the formation of the embryo in the seed of Phanerogams. But in the Thallophytes the male and female organs are often reduced to simple masses of protoplasm, "sperm-cell" and "germ-cell" (these being associated often in the same plant), bud-cells, *conidia*, &c. serving the purposes of vegetative propagation: the exact particulars and homologies are still obscure in many families.

The history of reproduction of plants has been greatly studied and much enlarged of late years; many important discoveries have been made in all classes; and the course of the processes in Phanerogams and the leafy Cryptogams is now pretty well known. Much still remains to be discovered in reference to the Thallophytes, especially the Fungi; but in the Algæ the processes of fertilization of germ-cells by spermatic corpuscles have been observed more clearly and definitely than in any other plants.

Conjugation.—The simplest form of sexual reproduction is that known as conjugation, or the fusion of two masses of protoplasm the one into the other, as has been already mentioned under the

head of cell-formation, p. 585, and which is adverted to in the description of the Thallophytes. The spore resulting from such union is termed a *zygospore* (Mucorini, Algæ, &c.). The conjugating cells are either motionless, or, as in *Botrydium* and *Acetabularia*, the motile particles of protoplasm (*zoospores* provided with cilia) combine one with another to reproduce the plant. In other cases the germ particle is stationary while the sperm particle exhibits active movements. Generally both sperm particles and germ particles are uncovered masses of protoplasm, the cell-wall not being formed around the germ mass until after fertilization.

Further details relating to the various modifications observable in the reproductive cells are given in the sections relating to Cell-formation and to the separate natural orders of Cryptogams.

Sect. 3. Reproduction of Phanerogams.

The remarkable distinguishing character of this group of plants is the possession of *stamens* producing *pollen* and of *carpels* producing *ovules*, the latter containing a large cell, the *embryo-sac*, within which is the *germ* or *germinal vesicle*. The sperm-cell or pollen-grain falls on the stigma, elongates into a long tube, which traverses the style and comes into contact with the embryo-sac containing the germinal vesicle. As a consequence of this contact, the germ-vesicle becomes a cell, and this ultimately forms an embryo, as described in other sections. In Gymnosperms the pollen or sperm-cells are applied directly, without the intervention of style or stigma, to the nucleus of the ovule. The germ-cell here differs from that of Angiosperms, and is called the *corpuscle* (see *ante*, p. 358). It is supposed to be homologous with the germ-cell or central cell of Lycopods (p. 424). The differences in the development of the embryo of Gymnosperms and Angiosperms are treated elsewhere.

The formation of the reproductive organs closes the life-cycle of the plant either permanently, or, in the case of perennial plants, the periodic cycle of growth and the progeny thrown off, after passing through a quiescent stage of rest, germinate afresh into a new perfect morphological representative of the species.

Alternation of Generations.—Vegetative reproduction (*agamogenesis*) in its varied forms and sexual reproduction (*gamogenesis*) may be manifested in the plant at the same time, or they may alternate one with the other; thus the production of spores and the formation of a prothallus in Ferns is an asexual process alternating with the development of a perfect plant from the action of a spermatozoid in the central cell of the archegonium. Among

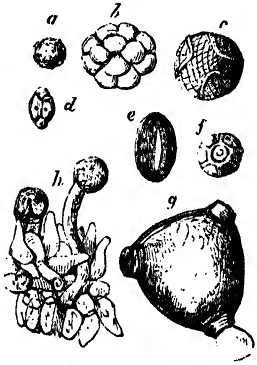
Thallophytes, as we have seen, great differences often exist in the same plant even, in both asexual and sexual modes of reproduction, the plant at one time and under one set of conditions reproducing itself in one way, at another time and under different conditions in another. For practical purposes such as the investigation of parasitical plants detrimental to animals or to other plants, it is of the greatest importance to know the life-history of the plants in question and the conditions propitious or adverse to its several modes of reproduction, as with such knowledge it may be possible to devise a remedy or avert the mischief.

Pollen-grains of Phanerogamia.

Sperm-cells.—Pollen-grains, the sperm-cells of Phanerogamia, correspond to the microspores of the heterosporous Vascular Cryptogamia; their protoplasm exhibits simply a nucleus, with granules of starch, oily matters, and other ordinary cell-contents. In this respect they approach the fertile cells of conjugating Algæ.

Structure.—In their simplest forms they are single cells, with a proper cell-coat or *intine*, and an outer cuticular coat or *extine*, mostly marked with irregularities, forming a kind of pattern on the surface, sometimes very elegant. In particular cases the outer coat is laminated, so that the pollen-cell appears to have several coats. In all cases the outer coat exhibits one, three, or many round holes or slits (*pores*) (fig. 602, *e*), where the inner coat is bare; in the pollen of *Passiflora*, *Cucurbita*, &c. there exist lid-like covers over the pores (fig. 602, *c*). Bands or furrows generally passing along the long diameter of the pollen-cell are frequent, varying in number according to the species: but these bands are generally only visible in the dry state.

Fig. 602.



Pollen-grains, magn. 100 diameters: *a, Bellis*; *b, Acacia laxa* (compound grain); *c, Passiflora cærulea*; *d, Periploca græca*; *e, Tradescantia*; *f, Cichorium Intybus*; *g, Epilobium montanum*; *h, Lathræa squamaria*, forming pollen-tubes among the cells of the stigma.

Form and Size.—The form and size of pollen-grains vary very much, as may be observed even in the few examples here figured; but although there may be a general resemblance throughout particular genera, and even Orders, they do not often afford good or regular systematic characters. They sometimes vary in different genera of the same

order, in different species of the same genus, e. g. *Viola*, and even in the same species, e. g. *Fuchsia, Primula, Mimulus.* The most frequent cases of agreement in allied plants occur when they possess *compound* pollen-grains (fig. 602, *b*, *d*), consisting of a number of pollen-cells permanently coherent together. The most striking cases of this are those offered so abundantly in Orchidaceæ and Asclepiadaceæ as to form valuable systematic characters in these Orders. These *pollen-masses* or *pollinia* consist either of the entire mass of pollen of an anther-cell, or of a half, quarter, eighth, or smaller fraction, so numerous in some genera as to appear like granules merely coarser than ordinary pulverulent pollen.

Formation of Pollen.—The existence of pollen-masses and compound grains is readily accounted for by the history of the development of pollen, which agrees in the main points with that of the spores of Mosses &c. (p. 429). The parenchyma in the central region of each lobe of a young anther presents two perpendicular rows of cells, one corresponding to each of the four primary loculi, different in character from those which are to form the walls. The cells in these series multiply by division to a considerable extent; and ultimately each forms a free cell from its whole contents—the parent cell of the pollen. These are set free by solution of the walls of the parenchymatous framework in which they have been developed, and they then lie as loose cells in the loculi or chambers of the anther thus formed. Each parent cell divides into four chambers; and each of these chambers (special parent cells) produces a pollen-cell, in the case of simple pollen-grains set free by the solution of the special parent cell. In quaternary pollen (fig. 602, *d*) the membranes of the special parent cells are not dissolved, and thus the pollen-cells are held together in fours; and the more complex conditions arise from the membranes of the parent cells of anterior stages persisting sufficiently to hold their progeny together. The mode of formation of the pollen in the special parent cells is by some attributed to cell-division; but the more generally adopted view is that it is formed by free-cell formation. The nucleus of the parent cell divides into two; between these two a quantity of granules of protoplasm are aggregated together in a direction across the parent cell: these granules are suddenly seen to be divided by a line, the first indication of the cell-wall between the two cells so produced; these two again subdivide; and thus four pollen-cells are ultimately found in one parent cell. The pollen-masses of the Asclepiadaceæ, and perhaps of some Orchidaceæ, result from a different process: in these the outer layers of the primary parent cells do not develop cells in their interior, but become conjoined into a cellular pellicle forming a sac or purse enclosing all the pollen-grains formed within.

The pollen-cells acquire their cuticular coat after they have become free; but part of the material of this structure appears to be derived from the dissolved membranes of the parent cells.

Zostera presents a remarkable exception to the usual character of pollen-grains, the cells here having the form of short cylindrical filaments with but one coat, *i. e.* without a cuticular layer. In these a rotation

(p. 549) of the cell-contents may be observed, which is likewise occasionally to be seen in recently formed pollen-tubes of other plants. The minute starch-grains of the cell-contents are noticeable as exhibiting a molecular motion, which was at one time imagined to be of vital character, and might lead the inexperienced to suspect the existence of minute spermatozoids.

Examination of Pollen.—Pollen-grains should be examined first as dry or opaque objects, as their form and dimensions are altered by endosmosis when immersed in fluids. Oil of cloves, syrup, glycerine, or naphtha are convenient fluids for examining pollen. A large number of pollen-cells, illustrative of their form and size, are given in the 'Gardeners Chronicle,' 1876, pp. 516 and 548. The discrepancies in the descriptions given by various authors depend on the conditions under which the pollen is examined. In the anther, and immediately after expansion, it is generally globular, but it often speedily assumes quite a different shape. When the pollen is transported by the wind, it often happens that the flowers are relatively unattractive, and the individual pollen-cells relatively small and smooth. In insect-fertilized flowers, on the other hand, the flowers are attractive and the pollen spiny or furrowed (Bennett). Too much stress, however, must not be laid on this point.

Pollen-grains of Gymnospermia.

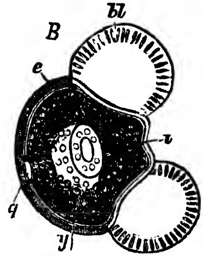
The pollen-grains of the Gymnospermia present a modification of the structure above described. They are not simple cells, but produce in their cavity, even before they are discharged from the anther, minute daughter cells, from one of which the pollen-tube is developed, and adherent to that side of the pollen-grain where the slit exists in the outer membrane. This formation is analogous to what is seen in the microspores of *Selaginella*, which in like manner produce a rudimentary *prothallus* (p. 425).

According to Schacht, in *Taxus* and *Cupressus* the pollen-cell only divides so as to form two unequal portions, of which the larger develops into the pollen-tube. In *Larix* and *Abies* (fig. 603) the pollen-grains appear to consist of a central and two lateral cells of different appearance to the central cell. These lateral projections are often finely reticulated, and are mere vesicular protrusions of the extine. The central body is the true pollen-cell, in which cell-division goes on, as in the case of *Cupressus* above mentioned, but with the difference that three or four daughter cells of unequal size are produced instead of one, the uppermost and largest of these new formations being developed into the pollen-tube, which passes through a rent in the extine, the other forming a kind of suspensor. Strasburger dissents from this view, and says that there are never more than two cells, the one marked *q* being a simple fissure or rent. The pollen-tube, according to him, is the result of a protrusion of the intine and not of the whole cell.

Tchistiakoff's researches into the mode of formation of the pollen of Conifers are remarkable as showing varying degrees of complexity and of transition between the formation of new cells by division and the process

of free-cell formation; and they establish an homology with the mother cells of the antherozoids of Cryptogams. The processes are somewhat complex; but if the lamination of the cuticle and cell-wall be borne in mind (p. 520), and the differentiation of the protoplasm into portions of varying density (p. 495) and crystalloid form be remembered, the stages of the process will be more readily understood by the student.

Fig. 603.



Pollen of Spruce Fir, after Schacht: *bl*, the vesicular protrusions of the extine; *e*, the extine; *y*, the apical cell, which develops into the pollen-tube; *i*, the intine; *q*, the lowermost cell of the male prothallus in contact with the intine (according to Strasburger, this is no cell but merely a fissure).

Tchistiakoff's researches show that the pollen of these plants is divisible into two groups, those with and those without vesicular protrusions or air-bladders. In both cases the mode of formation of the extine is identical. In both cases it consists of two layers; but where there are no air-bladders the two layers of extine are formed simultaneously. In the opposite case they are formed in succession, there being at first between the two an interspace filled with gelatinous fluid, which absorbs much water by endosmosis. The interspaces therefore become much distended, and ultimately form the air-bladders attached to the grain, the fluid contents disappearing. The net-like markings on these bladders are due to the remains of protoplasmic threads adherent to the extine. As to the division of the pollen-cells and formation of a male prothallus, M. Tchistiakoff admits three types:—1, that of *Cupressus* and other genera; 2, that of *Larix* &c.; 3, that of *Abies* &c. In all cases the starch in the cells becomes dissolved, the cell-wall (intine) swells up and becomes more hygroscopic, so that by its distention it throws off the cuticular extine, when the pollen-tubes begin to grow or germinate. While these changes in the intine are taking place, the outermost portion of the protoplasm becomes developed into a separate layer of globules or crystalloid masses surrounding the whole or only a portion of the plasma or cell-contents. The formation of the new cells may take place simultaneously with, or after, the differentiation of this peripheral layer of protoplasm, which, in the latter case, takes no part in the division.

In the *Cupressus* or *Thuja* type, the pollen-cells either do not divide, or each divides into two cells. The starch is dissolved, the nucleus divides into two: of these, one becomes more homogeneous, denser, and more transparent than the other, and resembles the homogeneous beak of the zoospores of Algæ. Both may be surrounded by the layer of protoplasmic globules just described, or one only.

In the *Larix* type, instead of two subdivisions of the plasma only, the two first formed divide again. In the case of the last subdivision a portion of the plasma becomes denser and more homogeneous, as in the former case. In *Pinus* two or three subdivisions take place, the cells so formed constituting a *suspensor*, the cell-division being preceded by changes in the protoplasm, as in the case of *Thuja*. The third cell is formed subsequently to the others, and is of a hemispherical form, separated by a partition from the second cell of the suspensor, but having no direct communication with the cell-wall or intine; nevertheless the mode of formation of the partition is the same. That portion of the protoplasm

in contact with the partition separating it from the second cell of the suspensor now secretes a cell-wall over the hemispherical portion of dense homogeneous protoplasm found in that situation, and the new cell is formed.

In the *Abies* type the two first cells of the suspensor are formed as above indicated; but the third is formed by true free-cell formation, and is quite detached from the suspensor. In the early stages it is like that of *Pinus*; but subsequently it may become completely isolated and divided into secondary and tertiary subdivisions, often in a spiral direction. In the germination of the pollen-tube, the intine of the larger of the two cells into which the primitive one divides alone forms the tube. In *Pinus* there may be more than one pollen-tube, in either case very large. In it is sometimes formed, by free-cell formation around a nucleus, a large cell, which becomes ultimately liberated by the absorption of the walls of the pollen-tube.

The new cells formed by free-cell formation and attached to the suspensor, as well as those formed freely in the pollen-tube in the course of its formation, are to be considered, according to this author, as the rudiments of the mother cells of the antherozoid, the presence of which Hofmeister had previously suspected. The cells of the suspensor correspond precisely to the cells of the male prothallus of *Isoëtes.*

In the Phanerogams, when a pollen-grain falls upon a *stigma* in its proper or "receptive" state (known by the presence of a saccharine secretion), the inner coat is protruded in the form of a blind pouch (fig. 602, *h*) from one or more of the pores or slits of the pollen-cell itself, and, nourished by the stigmatic secretions, grows into a tube of great tenuity, which makes its way through the loose stigmatic cells, and passes down the canal of the style into the cavity of the ovary, there following the course of the placentas when the ovules are numerous.

In the Gymnosperms the pollen-grains fall at once upon the ovules and pass into the micropyle, sending down their pollen-tubes (here developed from one of the daughter cells, which penetrate through the proper coat of the pollen-cell) into the substance of the nucleus of the ovule, towards the deep-seated embryo-sac.

The formation of imperfect pollen-tubes may sometimes be caused by placing pollen-grains in syrupy fluids; but when they are placed in dilute sulphuric acid &c. the extrusion of the inner coat which results is mostly a process of mechanical expansion, and the projecting pouches soon burst and discharge the contents of the cell, owing to endosmotic action.

Ovules of Phanerogamia.

The ovules of Phanerogamia are all constructed according to some modification of one general plan, which has been already described (p. 137). In the succeeding paragraphs some further details as to its history may be given.

Ovules of Gymnospermia.

The ovules of the Gymnosperms, Pinaceæ and their allies and Cycadaceæ, are produced upon open carpels, so that the pollen-grains have direct access to the micropyle (fig. 607, A, *a*). In *Pinus* two of these occur at the base of the carpellary scale. Each consists of a nucleus (or macrosporange) with only a single integument (fig. 605, A). In this first figure the primary embryo-sac, or "macrospore," is represented in the centre as still very small. Before the pollen-grains fall on the micropyle of the ovule, the

Fig. 604.

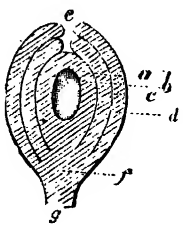


Fig. 605.

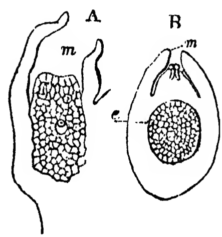


Fig. 604. Diagrammatic section of an ovule: *a*, nucleus; *b*, embryo-sac; *c*, inner coat; *d*, outer coat; *e*, micropyle; *f*, chalaza; *g*, funiculus.

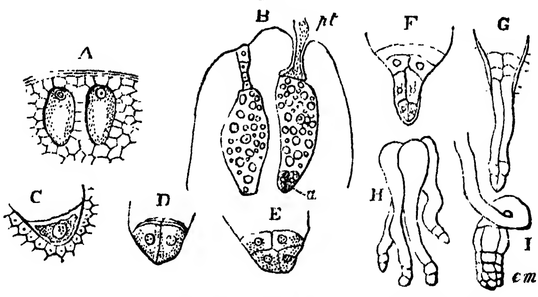
Fig. 605. Young ovules of *Pinus*. A. Vertical section at the time when the primary embryo-sac is a small cell in the centre of the nucleus: *m*, micropyle. B. Section of an older ovule: *m*, micropyle with two pollen-grains on the apex of the nucleus; *e*, the primary embryo-sac filled with cellular tissue. Magn. 50 diam.

embryo-sac becomes filled up, by free-cell formation, with delicate cellular tissue (endosperm-cells), which soon disappear, to be replaced by a fresh development at a subsequent period. This endosperm is the female prothallus. Fig. 605, B, represents a section of an ovule with an embryo-sac (*e*) filled up in this way, and two pollen-grains which have penetrated into the micropyle (*m*) pushing their pollen-tubes into the substance of the nucleus.

In the upper part of the mass of the last formed endosperm (*e*), from five to eight cells are found to expand more than the rest, forming *secondary embryo-sacs* or *corpuscula*. These are not formed in the superficial cells of *e*, but from cells of the second layer, so that each is separated from the membrane of the primary embryo-sac by one cell (fig. 606, A) These *corpuscula*, as they were called by Robert Brown, their discoverer, are very much like the archegonia in the internal prothallium structure of *Selaginella*. After a time the secondary embryo-sacs divide into an upper or *neck-cell*, and a lower or central cell, *egg* or *oosphere*. The neck-cell speedily

divides and subdivides to form the *rosette*, which surmounts the central cell. In the upper part of this latter is then formed, from subdivision of the nucleus, a very delicate cell, which is called the *canal-cell*. The mature corpuscle therefore consists of a large central cell surmounted by a rosette of small cells placed immediately beneath the wall of the primary embryo-sac, or separated from it by a funnel-shaped space. The pollen-tube, after remaining passive for a variable space of time, takes on active growth, traverses the endosperm, and arrives at the embryo-sac by the time the corpuscula are developed. It penetrates the wall of the embryo-sac, enters into and dilates the funnel-shaped space just mentioned, passes down between the cells of the rosette, pushing them on one side (*Taxineæ*, *Cupressineæ*), or causing their absorption and disappearance (*Abietineæ*) as well as that of the *canal-cell*, and finally penetrates into the cavity of the central cell. The changes which take place in this latter are, according to Strasburger, these:—disappearance of the original nucleus, and formation of four to eight new nuclei by condensation of the protoplasm and subsequent secretion of a cellulose wall around them. In this

Fig. 606.



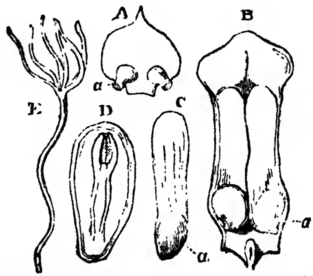
Development of embryo in Coniferæ (*Pinus*): A, upper part of the embryo-sac, with two *corpuscula* or archegonia; B, the same more advanced, the right-hand one with a pollen-tube (*p t*) in its canal and germinal corpuscles (*a*) at the base: C, D, E, successive stages of development of *a* in B; F, G, H, development of these cells into suspensors, at the end of one of which the embryo is produced, shown in I (*em*). Magn. 100 diam.

way four to eight new cells are formed by free-cell formation in the central cell after fertilization; these new cells divide so as to form cellular filaments, which break out through the bottom of the endosperm into the substance of the nucleus (fig. 606, F, G, H). At the ends of these filaments cell-division again occurs (I); and from the apex of one of these *suspensors* or *proembryos* is developed, by repeated cell-division in various directions, the embryo (I, *em*). At one stage (in *Thuja*) a single apical cell, the terminal one of a

group of five, from which ultimately all the tissues of the embryo are formed, recalls the single apical cell of Cryptogams, but it is soon lost by subdivision. As there are several corpuscles, and each produces four suspensors, a large number of rudimentary embryos are developed; but usually only one of all these rudiments is perfected.

That embryo which is fully developed gradually increases in size, and most of the structures above described disappear, so that the ripe seed exhibits a single embryo imbedded in a mass of endosperm or albumen (fig. 607, D), the latter originating apparently from the nucleus of the ovule. The radicle is covered by a *pileorhiza*, which is intimately blended with the substance of the endosperm.

Fig. 607.



Pinus sylvestris. A. Carpel with two naked ovules; *a*, micropyle. B. Carpellary scale of ripe cone, with seeds (*a*). C. A seed separated (*a*), having a wing-like process. D. Vertical section of the seed (C, *a*). E. Young plant from germinated seed.

The phenomena presented in other Pinaceæ, in *Taxus*, and in the Cycadaceæ agree in most of the essential particulars. There appear to be some curious peculiarities in the Gnetaceæ, which are not yet completely made out. In *Welwitschia*, whose anomalous structure has been described at pp. 137, 363, the embryo-sacs grow out of the primary embryo-sac *.

Ovules of Angiospermia.

The early history of the ovules of this group is analogous to that of the ovules of Gymnosperms, excepting in the particular that they arise from the placentas existing in closed ovaries instead of being developed upon the exposed surfaces of open carpels.

The ovules arise from the placentas as minute cellular papillæ (fig. 608), which gradually take form, and exhibit the regions and the modifications of their arrangement described in an earlier section.

The annexed drawing (fig. 609)—actual views, drawn to a scale, of the development of the minute ovules of *Orchis*—illustrates the gradual formation of the coats, &c. Fig. 609, *a*, represents a young ovule projecting out from the placenta, before it has become anatropous; the nucleus here consists merely of the embryo-sac surrounded by a single layer of cells,

* For further details, which the restrictions imposed by the size of this volume forbid us to enter upon, the student should consult Strasburger's 'Befruchtung bei den Coniferen,' his 'Coniferen und Gnetaceen,' and especially his treatise 'Zellbildung und Zelltheilung.'

which layer is absorbed as the ovule grows (*c*, *d*), so that the embryo-sac constitutes the whole nucleus of this ovule. In *a* the inner integument partially encloses the nucleus; in *b* the outer integument has grown up over this to a certain extent; and both are still more developed in *c*, where the inner coat has covered up the nucleus (leaving the *endostome*, p. 137), but itself projects from the outer coat. In *d* the outer coat has

Fig. 608.

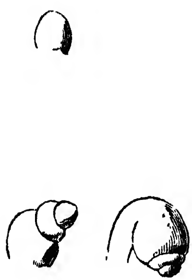


Fig. 609.

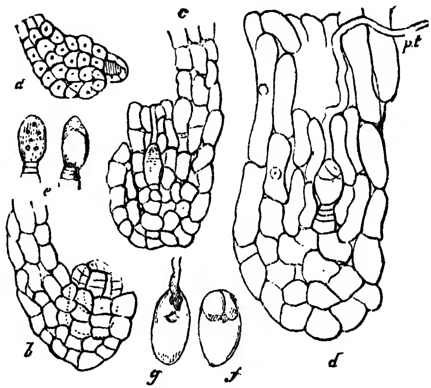


Fig. 608. Ovules, showing gradual formation of coats over the nucleus and progressive curvature.

Fig. 609. Development of the ovule of *Orchis Morio*: *a*, a young ovule, with the nucleus projecting from the inner coat; *b*, an older ovule becoming anatropous, with the outer coat growing up over the inner; *c*, section of a more advanced ovule; *d*, section of an ovule with the pollen-tube (*p t*) passing down the micropyle, and in contact with the embryo-sac; *f*, an embryo-sac extracted, with three germinal corpuscles; *g*, another, with the end of a pollen-tube adherent. Magn. about 100 diam.

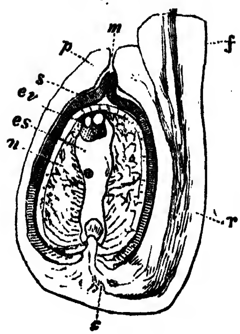
grown up over the inner, and the *micropyle* or *foramen* (p. 137) consists of a wide exostome and a narrow endostome, into which the pollen-tube (*p t*) has penetrated.

Ovules are seldom so small, or composed of so few cells, as the foregoing; more frequently the nucleus is a cellular mass of some size, and the coats are composed of several strata of cells. The outer coat is the *primine*, the inner the *secundine*, of Mirbel.

At the epoch when the pollen is scattered from the anthers, the ovule presents the characters which are illustrated in fig. 610, which represents the anatropous ovule of the garden Hyacinth. The nucleus (fig. 610, *n*) is surrounded (in this case) by two coats (*s* & *p*), which are perforated above by a canal, the micropyle (*m*); at the base of the nucleus is the chalazal region (*c*), whence the integuments (*s* & *p*) arise, and where the *raphe* (*r*), with its spiral vessels, ends. In the centre of the nucleus is a long sac (*e s*), the

embryo-sac. It is a large cell, filled with watery fluid and protoplasm, and contains at its summit the *germinal corpuscles* (*e v*), globular or oval masses of protoplasm, one of which becomes the germinal vesicle.

Fig. 610.

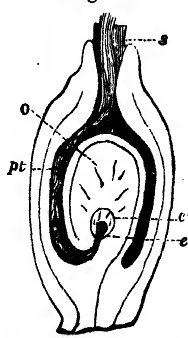


Vertical section of the ovule of the garden Hyacinth, just before impregnation: *f*, funiculus; *r*, raphe; *c*, chalaza; *n*, nucleus; *s*, inner integument; *p*, outer integument; *m*, micropyle; *es*, embryo-sac; *ev*, germinal corpuscles, one of which gives origin to the embryo. Magn. 25 diam.

Some authors assert that these corpuscles are *cells* before impregnation; but we hold that they are merely corpuscles of protoplasm, or rather free primordial utricles (p. 495), like the unfertilized spores of *Fucus* (p. 443). In fig. 612, A, *e v*, is shown the condition before fertilization in *Santalum*. Most observers consider that the germinal vesicles exist before fecundation; but Tulasne inclines to the belief that they are the first results of that process. In some cases, at the bottom of the embryo-sac, small cells (*antipodal cells*) have been seen, which are formed before the germinal corpuscles by free-cell formation, have only a temporary existence, and disappear after fertilization. The purport of these cells is not known.

Embryo-sac.—The embryo-sac is usually solitary, but in Crucifers there are several, one of which alone becomes fertilized. It exhibits different modes of development in different Orders of plants. In the Orchidaceæ the cell which constitutes the embryo-sac (fig. 609) very soon obliterates the surrounding cells, here a single layer, and comes to form the entire nucleus (*c*, *d*, *e*, *f*). In the Compositæ an analogous condition is met with. In the Leguminosæ the embryo-sac sometimes expands so much as to cause the absorption of the inner integument even before fertilization. In Gymnosperms the embryo-sac remains surrounded by layers of cells belonging to the nucleus till after fertilization has taken place.

Fig. 611.



Vertical section of the ovary, containing one ovule, of *Carduus*: *s*, base of the canal of the style; *o*, body of the ovule; *pt*, bundle of pollen-tubes, descending from the stigma; *es*,

The embryo-sac often only occupies a moderate part of the nucleus (fig. 610), and may then be a simple cylindrical or oval sac, or run out into pouches or *diverticula*, as occurs especially in Scrophulariaceæ. A remarkable condition occurs in Santalaceæ,

where the apex of the embryo-sac grows out from the micropyle to meet the pollen-tubes, and in such plants as *Ephedra or Welwitschia*, wherein the coat of the ovule is prolonged into a styliform process. In *Santalum album* and some other plants the embryo is developed entirely outside the nucleus, in the protruded part of the sac. Schacht says that the embryonic vesicles in *Santalum*, *Crocus*, and a few other genera, are much elongated; the lower end becomes rounded off into a cell, while the other end projects beyond the embryo-sac into a slender tubular prolongation into the micropyle. The sides of this are striated and gave rise to the appellation *filiform appendage*, which is considered by Strasburger to correspond with the *canal-cell* of Cryptogams. It is not clear whether the protrusion just alluded to is really from the embryo-sac or from the germinal vesicle.

Passage of the Pollen-tubes.—When the pollen-tubes are formed in the stigma they gradually elongate by growth at the apex into tubes which pass down the canal of the style when this exists, the latter being sometimes several inches long. The time occupied in this growth varies from a few hours to several weeks. In the Hazel-nut and other similar plants the pollen falls on the stigma in spring before the ovules are even formed. The pollen-tubes derive their sustenance from the tissues through which they pass, and mostly die away above as they grow below; and the stigma withers soon after the pollen-tubes have penetrated.

It is remarkable that the stigma remains fresh for a considerable time in unfertilized ovaries; and in the occasional cases of development of an unfertilized ovule, which has been observed in some diœcious plants, as *Cœlebogyne*, Hemp, *Mercurialis*, &c., the stigma does not wither.

Pollen-tubes.—The pollen-tubes are exceedingly minute, the diameter averaging from $\frac{1}{4000}$ or $\frac{1}{7000}$ of an inch. But Amici estimated the number of pollen-tubes formed from the pollen-masses of *Orchis Morio* at 120,000. Experiments have shown, however, that, under favourable circumstances, a very few pollen-grains suffice for even a many-ovuled ovary. Kölreuter found that when 25 pollen-grains were placed on the stigma of *Hibiscus Trionum*, 10–16 ovules were developed; with 50 or 60 grains, above 30 ovules; and 1, 2, or 3 at the most sufficed for the single ovules of *Mirabilis Jalapa* and *M. longiflora*.

The bundle of pollen-tubes proceeding from the style is distributed in fractions, or partial bundles, to the placentas, when several of these exist. The pollen-tubes make their way to the points of the ovules (figs. 611, *p t*, & 609, *d*, *p t*), and one or two enter the micropyle of each. Generally speaking, the tube ceases to elongate when it reaches the outer surface of the apex of the embryo-sac. Sometimes it runs onwards a little way (fig. 609, *g*), often depressing the membrane of the embryo-sac a little. According to Hofmeister, it actually breaks through into the embryo-sac in *Canna*. In all cases it contracts a firm adherence, and possibly a kind of conjugation takes place (fig. 612, B). The end of the

pollen-tube is always intact and without visible apertures. It never contains any cellular formation within it.

The arrival of the pollen-tube upon the surface of the embryo-

Fig. 612.

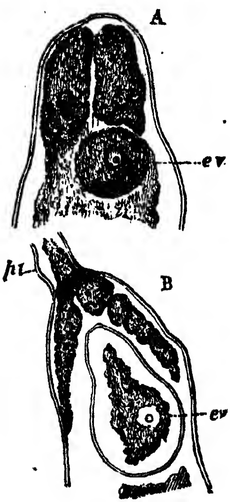


Fig. 613.

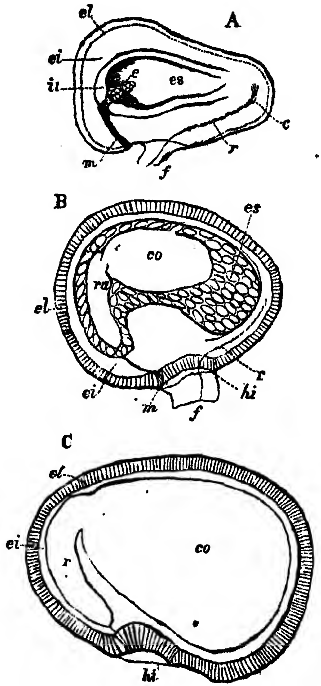


Fig. 612. Apex of the embryo-sac of *Santalum album*: A, just before impregnation; B, with the pollen-tube (*p t*) adherent, and a cellulose membrane upon the germinal cell (*e v*). Magn. 400 diam.

Fig. 613. Development of the embryo and seed of *Tetragonolobus purpureus*. A. Section of a seed soon after fertilization: *e*, embryo, in the upper end of *e s*, the embryo-sac, which in this stage is all that remains of the nucleus; *i i*, internal integument; *e i*, external integument; *e l*, epidermal layer; *m*, micropyle; *c*, chalaza; *r*, raphe; *f*, funiculus. B. Section of half-ripe seed, with internal integument obliterated, and the embryo-sac filled with endosperm-cells: *co*, cotyledon; *ra*, radicle of the embryo; *hi*, hilum; other references as in A. (This section represents a condition which is *permanent* in albuminous seeds.) C. Section of a ripe seed, in which the growth of the embryo has obliterated the endosperm, and the seed consists merely of embryo and testa; the latter is composed of the persistent external integument with its epidermal layer.

sac is followed by the development of one (rarely of more) of the

germinal corpuscles (fig. 612, A, *e v*) into the *germinal cell* (fig. 612, B, *e v*).

In *Orchis*, two of the corpuscles are sometimes developed into embryos. In *Citrus*, as may be readily observed in Orange-pips, two embryos are very frequently formed in the seed.

Development of the Embryo.—The development of the germinal cell into the *embryo* exhibits some variations in different cases. Most frequently the cell divides transversely, and the upper cell often elongates (sometimes dividing again by septa) so as to form a tubular confervoid filament, *proembryo* or *suspensor*, hanging from the top of the embryo-sac, and bearing at its lower end the true *embryonal cell*, which soon divides transversely and lengthwise into a more or less globose mass of cells, which are ultimately shaped into a mono- or dicotyledonous embryo. This suspensor is seen especially in Cruciferæ, Scrophulariaceæ, &c.; it is a single globular cell in *Potamogeton*. In *Zea*, *Fritillaria*, &c. the germinal cell does not elongate at all. In *Orchis* the *suspensor* grows out from the micropyle.

Changes in the Ovule during Fertilization.—Different changes are undergone by the parts of the ovule during the development of the embryo (fig. 613). In aperispermic seeds the embryo in its growth destroys all trace of the *nucleus*, and in the ripe seed lies immediately within the coats. In seeds with endosperm the commonest condition is for the embryo-sac to become filled with cells which are moulded over the embryo internally, and to expand externally until the surrounding tissue of the nucleus disappears, or remains only as an element in the coats of the seed. The tissue developed in the embryo-sac forms the endosperm. In Piperaceæ, Nymphæaceæ, and a few other cases a double perisperm is formed, endosperm being formed both inside and outside the embryo-sac, the latter being developed from the tissue of the nucleus.

No rules can be given for the homologies of the "coats" of the seed—the *testa* and *tegmen* or *endopleura*,—which are formed either from the *primine* and *secundine*, or from these and the *nucleus*—and sometimes from one alone of them, its tissues undergoing a different development in different layers.

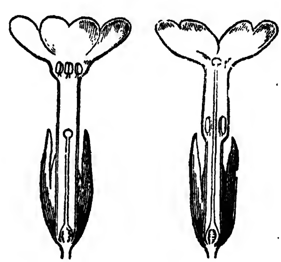
Fertilization.

The existence of distinct sexes in plants was inferred by Linnæus from certain arrangements which he described, and which would favour the process of fertilization, though it was soon seen that in many instances, as in the case of bisexual plants, the agency of the wind or of insects was required to convey the pollen to the stigma. Except in the instances just alluded to, it was the general opinion that self-fertilization was the rule in hermaphrodite flowers, *i. e.* that

the stamens of any given flower shed their pollen on the stigma of the same flower. Sprengel, however, and recently Darwin, have done much to prove that though a flower may be structurally hermaphrodite, it is usually functionally bisexual, and that a greater number of healthy seeds are produced when a cross-fertilization between the stamens of one flower and the pistil of another flower of the same species is effected. Darwin even states that in those cases where self-fertilization is the rule, a cross occasionally occurs.

Heterogonous flowers.—The facts just mentioned may be illustrated by the case of the common Primrose, the flowers of which are *dimorphic* or *hetero-styled*: in some the stamens are long and protrude beyond the corolla; in others the style is long and projecting, while the stamens are concealed within the corolla. Asa Gray, in order to emphasize the fact that the differences just alluded to are in the andrœcium and gynæcium, and not in the floral envelopes, or in one set of sexual envelopes, only proposes the term *heterogône* for such flowers. The most complete fertility ensues, *i. e.* the greatest number of fertile seeds is formed, when pollen from the long stamens is made (by insect agency or otherwise) to pass, not on to the short style of the same flower, but on to the long style of another flower. Other plants, such as *Lythrum Salicaria*, are *trimorphic*, having styles and stamens of three different lengths. Reciprocal fertilization is possible between any two of these; but the most perfect or *legitimate* fertilization occurs when the style of one flower is impregnated with pollen from a stamen of equal length with itself belonging to another flower. Fertilization occurring between stamens and pistils of different lengths is called *illegitimate*.

Fig. 614.



a *b*

Polyanthus: *a*, s[illegible] excluded; *l*, [illegible] mens included. (Seen in section.)

Mr. Darwin's experiments show that a similar difference in the degree of fertility exists in the case of the illegitimate unions of heterogonous flowers, as contrasted with legitimate unions between flowers of the same species, as is manifest between hybrid unions between two distinct species. For instance, there is the same or a similar difficulty in effecting a fertile union between different sexual forms of the same species, between a short-stamened and a long-styled Primrose, for instance, as there is in effecting a union between two distinct species. The union may take place, but it will be either infertile, or the number of seeds and the vigour of the seedlings will be diminished. Hybrids, then, may exist not only between two species, but even between differently constituted individuals of the same species. Sterility of hybrids, then, is an uncertain distinctive mark of species. Col. Clarke has even shown that the hybrid between two genera, *Elisena* and *Ismene*, is fertile. Mr. Darwin admits two subdivisions of hermaphrodite plants, viz.:—1, *heterostyled* or ditrimorphic flowers, as in the Primrose; and 2, "*cleistogamic*" flowers, or flowers adapted expressly

for self-fertilization, inasmuch as the flowers either do not expand or their buds are inconspicuous, and thus offer no attractions to insects. Such flowers are very common on Violets, though commonly overlooked. They yield more numerous seeds than the brighter-coloured flowers.

Monœcious plants like the Hazel, which have the sexes in different flowers on the same plant, may be subdivided into two classes, according as the anthers are ripe before the pistil, or *vice versâ*, the object clearly being to favour the cross-fertilization of different plants. Many hermaphrodite (structurally) flowers are organized in a similar manner.

Diœcious plants, or those with the flowers of the two sexes on different plants, must necessarily be cross fertilized, and, as we have just seen, many plants structurally monœcious are rendered practically diœcious by the different times at which the stamens and pistils respectively come to maturity. Among diœcious plants the difference between the sexes is sometimes remarkably great: thus among Restiaceæ, sedge-like weeds of Australia and the Cape, it sometimes happens that the male and female plants of the same species are so different that the female much more closely resembles the male of a totally different genus than it does the male of its own species. Of course this applies only to the general habit and appearance of the stem and foliage, and not to the intimate structure of the flowers. Lastly, we come to *polygamous* flowers, which Mr. Darwin divides into two subgroups, according as the three sexual forms are found on the same individual or on distinct plants. Of the latter case the Ash is an example; some trees bear in some seasons male flowers only, others female flowers only, and others hermaphrodite blossoms. The Ash, then, may be classed as triœcious. On the other hand the common Maple bears all three sorts of flowers on the same tree, and is thus monœciously polygamous. Other polygamous plants may be grouped into *gyno-hermaphrodites*, inasmuch as they exist under two forms—one of which bears female flowers only, the other hermaphrodite flowers, as in the common Thyme. Some of the Chenopodiums bear on the same plant hermaphrodite and female flowers, and may therefore be called *gyno-monœcious*. On the other hand there are "*andro-monœcious*" plants, or plants bearing on the same individual male flowers and hermaphrodite flowers, in some species of *Galium*. No case seems to be known of *andro-diœcious* plants, or plants producing hermaphrodite flowers on one individual, and males on another.

In the case of the sexually dimorphic flowers the pollen-cells are sometimes different in size in the long and short stamens respectively. At other times no such difference can be detected, and, as a rule, there is no relation between the size of the pollen and the length of the style.

Heterogonous flowers are still the exception. Mr. Darwin points out that flowers already adapted by their structure for cross-fertilization by insect agency do not need to become heterogonous; hence, so far as is known, there are no heterogonous flowers in Orchids, Labiates, Leguminosæ, and other large orders, the conformation of whose flowers is adapted to insect agency.

Though cross-fertilization is thus shown to be advantageous and very general, yet there are some cases where every adaptation seems to be made with the view of securing self-fertilization, as in the *cleistogamic* flowers, above referred to. In *Dombeya* the staminodes or sterile stamens are longer than the fertile ones, and are endowed with a power

of movement in virtue of which they curve downwards and outwards, so as to come into contact with the fertile stamens, whose anthers open outwardly. In this manner the staminodes become dusted with pollen, and then become uncoiled, assume an erect position, so as to come into contact with the stigma, whose curling lobes twist round them and receive the pollen from them.

Hildebrand gives the following arrangement of the distribution of sexual relations in flowering plants:—

A. Male and female organs in different flowers (diclinous); self-fertilization consequently impossible, and foreign impregnation, accomplished by insect agency or wind, indispensable. Under this head are included the flowers of diœcious and monœcious plants.

B. Male and female organs in the same flower (monoclinous).

1. One sex developed before the other (*dichogamous*). Those flowers in which the male organs reach maturity before the female ones are called *protandrous*, and those in which the female reach maturity before the male *protogynous*; self-impregnation is thus naturally prevented, and fertilization is accomplished by insect agency.

2. Both sexes developed at the same time.

a. Flowers opening.

i. Anthers remote from the stigma.

A. Length of style on different individuals of the same species diverse (*Heterostylia*). Self-impregnation is not prevented; but, in comparison with impregnation through insect agency, it is either entirely useless for seed-formation, as in *Pulmonaria officinalis*, or effected only with unimportant results, as in *Primula sinensis*.

B. Length of style on different individuals of the same species equal.

o. Sexual organs changing their reciprocal position during the development of the flower. Self-impregnation avoided; impregnation by means of insects facilitated.

oo. Sexual organs remaining unaltered in position during the development of the flower.

† Insect agency necessary to fertilization; self-impregnation in fact impossible, foreign aid indispensable, as in Orchideæ; or self-impregnation possible, but not indispensable, foreign impregnation more frequent, as in Asclepiadeæ.

†† Insect agency not necessary to fertilization. Self-impregnation possible, but impregnation also performed by insects.

(The possibility of self-fertilization is evident—1, where the flowers are erect and the filaments are longer than the styles, as in *Vitis*, *Chenopodium*, &c.; 2, where the flowers are pendent and the filaments are shorter than the styles, as in *Fritillaria imperialis*, *Convallaria majalis*, &c.; but as all these flowers are visited by insects, cross-impregnation probably often takes place.)

ii. Anthers near the stigma.

* No fruit formed without impregnation by insects: *Corydalis cava.*

(It would scarcely have been deemed credible that self-fertilization was impossible in such an instance as *Corydalis cava,* where the anthers are closely appressed to the stigma, and in which self-impregnation appears inevitable. In his experiments, however, Hildebrand discovered that when this plant was secured from the visits of insects, and also when the pollen was artificially applied to the stigma of the same flower, no fruit was set. To obtain perfect fruit he found it necessary to impregnate the stigmas of one plant with pollen from another.)

** Fruit formed as a result of self-impregnation, but impregnation by insects not excluded.

(Instances of undoubted self-fertilization of individual flowers are known in the genus *Fumaria*, in *Salvia hirsuta, Linum usitatissimum, Cephalanthera grandiflora, Ophrys apifera,* &c.; but the number and quality of seeds borne is less than where cross-impregnation is effected.)

β. Flowers not opening (*cleistogamous*).

Self-impregnation alone results, every foreign impregnation being excluded; but these plants all have other flowers which open and are thus exposed to the possibility of extraneous impregnation.

The general conclusions that may be drawn from the above facts are thus given by Hildebrand:—1. The arrangements in the majority of flowers are such that no self-impregnation takes place, but a transport of the pollen from flower to flower is accomplished instead. 2. Insects are necessary in most cases for the conveyance of the pollen. 3. When the access of a flower's own pollen is prevented, it necessarily follows that self-impregnation is impossible. 4. In those cases where self-impregnation is possible, or even unavoidable, the possibility of foreign impregnation is for the most part not excluded. 5. In these cases insects are active, and accomplish the impregnation of the flowers. 6. There is probably no flowering plant to which access of foreign pollen, at least to a portion of its flowers, is possible, and continued self-impregnation alone possible; therefore no flowering plant which furnishes a proof against the general law which negatives self-fertilization. 7. By experiments it has been found that where, by accident or design, the pollen of a flower falls on the stigma of the same flower, fertilization either does not follow, or, when it does occur, the quantity of seed is less than where foreign pollen is employed. 8. A gradual transition may be traced, starting from those cases where self-impregnation is utterly impossible, to those where it is possible and evident, but not to the exclusion of the possibility of a foreign impregnation of the flowers. 9. The sexual relations and mode of fructification do not invariably tend towards the morphological affinities of the flowers. In some isolated families the sexual conditions of all members are alike; in other families, again, and even genera, they are essentially different. The sexual relations, therefore, have not developed with equal pace and in the same way as the

morphological relations in the transformation and perfection of flowering plants.

The inferences drawn by Darwin, Hildebrand, Delpino, and others, however, have lately been questioned by Henslow, whose conclusions are as follows:—1. The majority of flowering plants are self-fertile. 2. Very few are known to be physiologically self-sterile. 3. Many are morphologically self-sterile. 4. Self-sterile plants become self-fertile (*a*) by withering of the corolla; (*b*) by its excision; (*c*) loss of colour; (*d*) closing; (*e*) not opening; (*f*) absence of insects; (*g*) reduction of temperature; (*h*) transportation. 5. Highly self-fertile forms may arise under cultivation. 6. Special adaptations occur for self-fertilization. 7. Inconspicuous flowers are highly self-fertile. 8. Cleistogamous flowers are always self-fertilized. 9. Conservation of energy in reduction of pollen. 10. Relative fertility may equal or surpass that of crossed plants. 11. It does not decrease in successive generations. 12. It may increase. 13. Free from competition, self-fertilized plants equal the intercrossed (*a*) as seedlings, (*b*) planted in the open ground. 14. They may gain no benefit from a cross from the same or a different stock. 15. They are as healthy as the intercrossed. 16. They may be much more productive than flowers dependent on insects. 17. Naturalized abroad they gain great vigour, and, 18, are the fittest to survive in the struggle for life.

As regards the question of self-fertilization, or cross-fertilization, and their respective consequences favourable or otherwise, it would seem that both the views above cited, different as they seem, may be correct. What is now required is a series of experiments and observations to ascertain under what precise circumstances each method of fertilization is adopted and the reasons and consequences thereof.

Hybridization.

Cross-breeding.—The treatment of the subject of the sexual reproduction of Plants would be incomplete without some notice of the phenomenon of *hybridization*, or cross-breeding between distinct species of plants.

From the difficulties arising partly from the minute size of the structures, partly from the comparatively recent date of any accurate knowledge of the sexual organs of Cryptogams, we are at present only acquainted with a few certain facts in reference to the cross-breeding of species in that Subkingdom. It has long been known, however, that in collections of cultivated Ferns forms spring up from time to time presenting new characters, more or less intermediate between well-known natural species; and these have been commonly accounted hybrids. The discovery of the phenomenon of fertilization on the prothallia of Ferns gives a new support to the supposition that such plants are hybrids, although the question is still insufficiently supported by evidence.

Cross-breeding in Algæ.—We possess, however, some facts of importance on this subject relating to the Fucaceous Algæ. Thuret took advantage of the extrusion of the germ-cells and spermatozoids in Fucaceæ before impregnation to collect these separately and experiment on the degree to which hybridization was possible. He found that spermatozoids of *Fucus serratus* and *F. vesiculosus* would not fertilize the

spores of *Ozothallia vulgaris*, and *vice versâ*. Neither could the spores of *Himanthalia lorea* be fertilized by *Ozothallia vulgaris* or *Fucus serratus*, nor the spores of *Fucus serratus* by the spermatozoids of *F. vesiculosus*. But the spores of *F. vesiculosus* impregnated by the spermatozoids of *F. serratus* became fertile and germinated; which fact is the more interesting since *F. vesiculosus* is a variable plant in its natural state, while the others named exhibit comparative fixity.

Cross-breeding in Phanerogamia.—The existence of hybrids in Phanerogams, produced by impregnating the ovule of one plant with the pollen of another, is a well-ascertained fact; and indeed hybrids are produced at will, within certain limits, by gardeners.

It is necessary to distinguish here between *true hybrids*, or *mules*, resulting from the crossing of distinct species, and simple *cross-breeds* (or *metis*) commonly included under the name of hybrids by gardeners, and resulting from the crossing of varieties (p. 159) of the same species. It is from the last operation that the great majority of the "hybrids" produced in favourite florists' flowers, such as *Pelargonium*, *Fuchsia*, &c., are derived—this cross-fertilization usually presenting little difficulty, and commonly occurring naturally where large quantities of varieties are grown together.

The ready cross-fertilization of varieties spontaneously, places great difficulty in the way of growing the varieties of cultivated vegetables for seed. The different varieties of the Cabbage, Turnip, Pea, &c. are difficult to preserve pure as seeding-plants in large gardens or seed-growing establishments, from the fact of insects and the wind carrying the pollen from plant to plant.

True hybrids, as a rule, subject to some remarkable exceptions, such as *Philageria*, *Elisena*, and *Ismene*, &c., can only be produced between plants belonging to the same genus. When they are more diverse than this, they will usually not cross; and even within the limits of genera, species will not always breed together.

Generic difference in Flowering plants usually involves difference in the structure of the reproductive organs, the size of the pollen-tubes, &c.; we are therefore not surprised at the above statement; numerous instances, however, occur of the refusal of nearly allied species to cross, where we cannot detect any structural differences between them. It has also been shown that in heterogonous flowers (p. 636) the different forms of the same species are more or less sterile when intercrossed.

The tendency to cross-breeding is less common than is frequently supposed. Gærtner, the greatest experimental authority on this point, states that in 10,000 sets of experiments, carried on during many years, he only obtained 259 true hybrids. It is found impossible, for example, to cross the Gooseberry and the Currant (two species of *Ribes*), the Apple and Pear (two species of *Pyrus*), the Blackberry and Raspberry (allied species of *Rubus*), &c.

Besides this peculiar indisposition to hybridize, there exists an obstacle in nature, in the greater facility with which an ovule receives the influence of its own pollen; Gærtner describes this phenomenon under the name of *elective affinity*, stating that when the natural pollen and that of another species are placed upon a stigma, the foreign pollen remains inert: and even when the natural pollen is applied a little time subsequently to the foreign pollen, it acquires the supremacy, and the embryos prove true, and never hybrids.

Hybrid Plants.—When species are crossed, the result from the hybrid seed is a plant differing from both parents, bearing more or less relation to one or the other, as regards form and habit, in different cases. Gardeners do not appear agreed as to the kind of influence exerted by the male and female parents respectively in determining the character of the mule. Gærtner states that in hybrids of *Digitalis* the mules most resembled the female parent, while in *Nicotiana* the reverse appeared; and he believes no law can be laid down in regard to this point.

The seeds ripened after hybridizing generally form but a fraction of those matured under natural circumstances. Thus, according to Gærtner, hybrids of *Verbascum Lychnitis* with *V. nigrum* gave but 63 per cent. of the normal number, with *V. Thapsus* 21 per cent., with *V. pyramidatum* 3 per cent.; hybrids of *Dianthus barbatus* with *D. Armeria* 53 per cent., with *D. deltoides* 22 per cent., with *D. virgineus* 1 per cent., &c. Darwin, however, shows that the sterility of crossed species as well as that of their offspring varies from zero to complete fertility. Moreover diœcious plants appear less prone to hybridize than those with hermaphrodite flowers.

The seeds originating from a process of hybridization produce plants varying very much in their degrees of fertility. It appears that the marjority are barren; in many cases only a portion of the seeds formed produce fertile plants; while in a few cases the hybrid plants are nearly as fertile as those of their parent species when unmixed. Some species can be crossed readily, but the hybrids resulting are very sterile; on the other hand, some plants crossed with difficulty yield very fertile offspring. The degree of sterility differs in two species when reciprocally crossed. It is observed, also, that in fertile hybrid plants the flowers earliest opened are the most fertile, or sometimes are the only ones that ripen seed, subsequent flowers often developing fruits the seed of which are destitute of an embryo.

This barrenness of the later flowers, from deficient vital force, is in some degree analogous to what we sometimes observe in cut flowering stems of succulent plants. We have seen the ovary swell and one or more seeds become extensively developed on a cut spike of *Aloe* and on an umbel of *Crinum*, thrown aside to wither. The seeds, however, were quite "blind," the expansion consisting of an abnormal development of the integuments of the ovule, the nucleus and embryo-sac remaining unchanged.

Relative Fertility of Hybrids.—In some fertile hybrids it is observed that their progeny forming the second and third generations become more fertile than the original hybrid; it is noticed, however, that their descendants usually exhibit a great tendency to vary in external character, and often return more or less to the type of one of the parents.

Hybrid characters seem, from the researches of Naudin, not to be permanent. The plants revert, as above said, to the type of one or the other of the parents. What are termed "*sports*" by gardeners, *i. e.* shoots differing in character from those on the other portions of the plant, are frequently, but not always, due to the dissociation of hybrid or metis characters, or they may present the characters of some more remote ancestor.

Reversion.—The impregnation of the ovules of hybrids by the pollen of plants of either parent species produces more fertile seeds than are formed after self-fertilization of hybrids. The progeny in such cases return more or less to the parent type, on the side from which the pure pollen comes, and by a repetition of such fertilization the hybrid characters are lost in a few generations.

It is an interesting fact that the ovules of hybrids are sometimes more freely fertilized by pollen of a strange but pure species, than by their own: thus the hybrid *Nicotiana paniculato-rustica,* which usually did not ripen more than 13 good seeds in a capsule, produced with the pollen of *N. paniculata* 36, with *N. rustica* 20, and with the pollen of *N. Langsdorfii* (a totally new element in the crossing) 16. In another experiment, when this hybrid produced no seed by self-fertilization, 10 good seeds resulted from crossing with *N. Langsdorfii.* (For a general review of the subject of Hybridization, see Darwin, 'Variations of Animals and Plants,' ed. 2, vol. ii. p. 157, and Anderson Henry, Proc. Soc. Bot. Edinburgh, 1867.)

A curious phenomenon has been observed in the garden plant called *Cytisus Adami,* obtained either by grafting or by true hybridation of the two kinds of Laburnum, *Cytisus Laburnum* and *C. purpureus.* The plants in many instances exhibit a partial separation or dissolution of the hybrid characters in the products of different leaf-buds: on the same tree in which part of the branches bear blossom of the hybrid character, other shoots occur, some of which revert to the character of *Cytisus Laburnum,* others to that of *C. purpureus,* the other parent. In some of the shoots, moreover, unequally combined characters of the parents are observed in different flowers of the same raceme.

In some cases it has been found that the reverted or pure shoots bear perfect seeds, while the hybrid blossoms were barren.

Cytisus Adami has generally been supposed to be an ordinary hybrid; but it has recently been stated that it originates when *C. purpureus* is grafted on *Cytisus Laburnum,* offering thus an instance of affection of the stock by the scion analogous to that of the variegated Jasmine and *Abutilon* referred to previously (p. 618). If this prove true, it will be a most important physiological fact, opening up a very interesting field for experiment, and likely to lead to practical results of high value in the cultivation of fruit-trees. Certain *sports* of Roses have also been accounted for on the supposition that they have originated as graft-hybrids; but the evidence on the point is not as yet sufficiently conclusive.

In some cases the action of hybrid pollen is made manifest in the production of changes in the envelopes of the seed, and even in the appearance of the fruit, so that the influence has been exerted not only on the offspring but also on the mother plant. As an illustration may be cited the case recorded by Vilmorin of a yellow-seeded Maize producing black seeds when crossed with pollen from a black variety. Such cases, however, require strict scrutiny. (See Laxton, Proceedings Internat. Bot. Congress, London, 1866, p. 156, and Clarke in the same volume, p. 143; Darwin, 'Animals and Plants under Domestication,' ed. 2, p. 427; Maximowicz, as translated by Dyer in Journ. Hort. Soc. London, vol. iii. p. 161, 1872.)

Germination.

Requisite conditions.—Given a properly ripened seed with well-formed embryo, the period when the latter will begin to sprout or germinate varies according to the particular species, and according to external conditions. The general conditions favouring germination are exposure to a certain temperature, a certain amount of water, and access to oxygen gas, besides certain secondary or accidental influences. As regards temperature, germination may be carried on in some cases even at freezing-point; but it is rarely manifested beyond 40°–42° C., though vitality is not necessarily destroyed at much higher temperatures. The actual temperature most conducive to germination varies in different species.

Sachs's experiments on the growth of Wheat and Barley show that germination began below 5° C., in the French Bean and Maize at 9° C., and in the Gourd at 13° C.; but when the reserve material in the seed was used up, and the seedling had to procure its food from without, a higher temperature was needed. The highest temperatures noticed by Sachs are, for French Beans, Maize, and Gourds 42° C.; for Wheat, Barley, and Peas 37° or 38° C.

Water is a primary requisite in the germination of seeds, as it softens the tissues and enables the insoluble reserve materials to assume a soluble form. Free access to atmospheric air, or to the oxygen contained in it, is necessary for the carrying on of those chemical changes which are manifested during germination. If seeds be deeply buried, so that access of air be prevented, they do not germinate.

Weak solutions of chlorine, iodine, and bromine have been known to accelerate the process of germination, and camphor is also stated to be a stimulant to the growth of the embryo plant.

Effect of Electricity.—Electric currents are stated to hasten germination. When seeds are exposed to the action of galvanism, it is found that those around the negative pole of the battery germinate much more freely and quickly than those around the positive pole, and than those not submitted to the electric current. Bridgeman, in 'Gardeners' Chronicle,' Feb. 1, 1873, further notes that the radicles of the blackened and shrivelled seeds round the positive wire grew *upwards* into the air instead of downwards; and this observation confirms a similar one made by Blondeau.

Time required.—Many seeds germinate very quickly when placed under favourable conditions, especially those of Cruciferæ, Grasses, many Leguminosæ, Cucurbitaceæ, &c.; but the period varies even in seeds of the

same individual plant under apparently identical conditions. In general terms, the length of time required is long in proportion to the lowness of the temperature, the absence or presence of perisperm, its nature, the depth of sowing, &c. Seeds enclosed within a hard pericarp, endocarp, or testa, often remain a year or even more before germination; but in such cases the process may be accelerated by soaking the seed. Some seeds require to be sown at once or they lose their germinating power; others retain their vitality for a great number of years, though the stories relating to the germination of seeds taken from Egyptian mummies and Roman barrows will not bear the test of close examination. Better authenticated statements have shown that some seeds have retained their vitality after more than a century. Out of 368 species sown at Geneva by Alphonse de Candolle, 17 only grew after a lapse of 15 years. Fifteen out of 20 seeds of *Dolichos* grew after this period, 6 out of 20 of *Lavatera*, of the other 15 only 1–3 grew. Out of 288 genera whose seeds were sown under the auspices of the British Association by Dr. Daubeny and others, it was found that the majority had lost their vitality altogether after having been kept 10 years. Thirty-four species, about one seventh of the whole number, retained their vitality after 10 years, 20 species after 20 years, and 2 only, both Leguminosæ, maintained their vitality after 40 years. In both sets of experiments the greatest instances of longevity were found among the Leguminosæ, which are destitute of perisperm, while the Umbelliferæ, which have perisperm and much essential oil, seemed to lose vitality particularly soon.

Circumstances retarding Germination.—These will have been gleaned from what has preceded. Deprivation of water or oxygen gas, too low or too high a temperature, will all retard or even prevent germination, in extreme cases, by destroying the vitality of the embryo. Pure phosphorus retards germination, while anilin is stated to stop it completely, as arsenious acid and other poisons do. Exposure to light does not of itself retard germination, other conditions being equal.

Changes during Germination.—When germination begins the soluble matters contained in the seed are used up, while the insoluble ones are so modified as to become soluble. The ternary ingredients, especially starch, become converted into dextrin and glucose under the influence of a nitrogenous substance, *diastase*, which acts as a ferment. Thus in the process of malting, which is nothing but the germination of Barley stopped at a certain stage, the starch becomes converted into sugar, thus: starch with a composition of C 36 H 30 O 30+4 HO = 2 Glucose 2 (C 12 H 12 O 12) and Dextrin C 12 H 10 O 10 (Musculus). What brings about the ultimate transformation of grape-sugar, or glucose, or of dextrin into cellulose is not known. Fatty substances lose a portion of their carbon and form glucose. Nitrogenous substances during germination undergo analogous transformations; thus, among Leguminosæ, the albuminoid matters become transformed into *asparagin*, a soluble nutritive substance, which is conveyed from cell to cell, according to the requirements of the case. The transformation of the albuminoids into asparagin takes place as well in obscurity as under the influence of light. Oxygen is fixed during the process, and C and H are liberated, the sulphur being oxidized and changed into sulphuric acid. Gorup-Besanez has also shown that in Beans there exists a diastasic ferment capable not only of effecting the transforma-

tion of starch into sugar, but also of fibrine into peptone. A similar formation of ferments has been observed in the case of leaf-buds about to develop (Kossmann). As the seedlings grow and become exposed to the light, the asparagin disappears.

During germination Boussingault observes that the plant comports itself as an animal does, or like an egg during incubation. It grows on the reserve materials accumulated in the tissues, oxidizes them, emits carbonic dioxide, evolves heat, as happens in other chemical changes, the final result being the nutrition of the embryo plant.

The Perisperm.—With reference to the part played by the perisperm, it may be stated that it is a store-house of nourishment upon which the young seeds draw before they have acquired the power of feeding for themselves. Hence we often find that in the case of those seedlings which have from the first a well-developed feeding-apparatus in the shape of green seed-leaves (as in the Turnip, Mustard) the perisperm is at the time of germination either non-existent or in very small proportion. On the other hand, where the perisperm is abundant, there the seed-leaves are very small and inconspicuous. The difficulty in inducing some seeds to germinate is connected with the fact that the seedling plant is often able to feed upon the perisperm, but is not able to shift for itself; hence when the supply of albumen is exhausted, the seedling fails. M. Van Tieghem has lately made some experiments with a view to ascertain how the seedling plant gets its nourishment from the perisperm, and in the course of his experiments ascertained that the perisperm in some cases acts as a nursing mother to the young embryo, while in others the young plant merely helps itself to what it finds at hand. Albumen of an oily character undergoes a change of structure and composition—digests itself, in fact; and the young plant does but take up the products of this change in the tissue and constitution of the perisperm.

Floury perisperm, such as that of the Wheat, is passive. It is changed and ultimately absorbed and digested by the embryo itself. It is of the nature of food simply, and does not, as in the former case, also fulfil the office of a nursing mother. The germination of seeds and the length of time required for the process are thus seen to depend very materially on the nature of the perisperm.

Independence of the Parts of the Embryo.—M. Van Tieghem has ascertained that, under certain circumstances, the several parts of the embryo plant may be severed one from the other, and even themselves divided into fragments, and yet these fragments will preserve their vitality and grow independently. The cotyledons, if divided, will produce radicle and buds; thus a plant of a Sunflower was made to produce eight plants by dividing each of its two cotyledons into four. When the perisperm was removed from around the embryo of a Marvel of Peru, germination went on well for a time, but the plumule was arrested in its development, so that the perisperm seems to be required for the formation of the plumule, though the other parts of the embryo obtain sufficient nutriment from the stores accumulated in their own tissues. The same experimenter extracted embryos from the seeds, and placed them in an artificially prepared substance, resembling in constitution the perisperm, and he found that the embryos absorbed the artificial food and used it up in the production of new tissues, just as they would have utilized the stores in the perisperm.

CHAPTER VI.

MISCELLANEOUS PHENOMENA.

Sect. 1. Evolution of Heat by Plants.

In examining the cases falling into this section, it is important to separate them into two classes:—(1) those relating to the proper or specific heat of plants generally; and (2) those more remarkable instances of elevation of temperature occurring at certain periods of development in particular plants.

It being a well-ascertained fact that the chemical combination or separation of various elements found in plants is accompanied by increase or diminution of sensible heat, and that the process of evaporation, constantly going on in dry weather in healthy plants, is a cause of depression of temperature as the substance from the liquid passes off in the form of vapour, it is evident that the proper temperature of plants, and their organs and tissues, must vary greatly according to the circumstances in which they are placed. Yet, as the evaporation, and the fixation of carbon in a solid form from gaseous material—both "cooling processes"—are such preponderating operations in the nutritive and assimilative processes of vegetation, it seems scarcely possible, under ordinary circumstances, that plants should have a specific heat rising above that of the surrounding atmosphere.

The different power of conducting heat possessed by the several tissues, and, in the case of the woody tissues, the difference in the conducting-power according to the varying directions of the fibres, together with the disturbances arising from the unlike conductivity of the fluids and solid matters constituting the cell-contents, render it very difficult to arrive at any general conclusions as to the specific heat of plants.

From Dutrochet's experiments, made with a thermo-electric apparatus, it would appear that the specific heat of all parts of plants in their ordinary condition is rather lower than the temperature of the surrounding atmosphere. In cases, however, where evaporation was prevented by placing plants in an atmosphere saturated with moisture, the temperature sometimes rose from $\frac{1}{12}$ to $\frac{1}{3}$ per cent. above that of the atmosphere. Moreover a rise and a fall took place in the course of twenty-four hours, the maximum occurring between ten and two in the day, the minimum at midnight. It was further observed that the specific heat was only discoverable in the soft or green parts, not in the woody structures.

The experiments, however, which have been made to determine these points are by no means conclusive. It seems probable that the increased heat observed in the structures of plants when evaporation is restrained depends upon the slow combustion of carbon, which is enabled to manifest itself when the cooling influence of evaporation is removed.

The germination of seeds, in which carbonic dioxide is abundantly

evolved, is constantly accompanied by a rise of temperature, which is satisfactorily accounted for on chemical principles; and the "heating" of heaps of germinating seeds is the more marked in consequence of the "fermentation" (or decomposition through contact-action) by which it is always accompanied. In the case of Fungi, as shown by McNab (Gard. Chron. 1871, p. 1256) in *Bovista gigantea*, the temperature is higher than that of the air, owing probably to the formation of carbonic dioxide. Similar phenomena had been previously observed by Dutrochet in France and Marcet in England.

Heat evolved during Flowering.—The most remarkable instances of evolution of heat are those which occur during the flowering of plants. This rise of temperature appears to take place in all cases; but it is most strikingly displayed, of course, in plants which have a crowded inflorescence, and above all when this is surrounded by a structure confining the liberated heat, as in the spathes of the Araceæ, on which many observations have been made.

Arum maculatum, A. italicum, A. Dracunculus, Richardia æthiopica, Colocasia odora, &c., the male inflorescence of *Cycas circinalis*, the large solitary flowers of *Cactus grandiflorus, Bignonia radicans, Victoria regia*, &c., are among the recorded plants in which the rise of temperature has been observed.

The greatest evolution of heat, after the opening of the spathe of Araceæ, is at the part where the male flowers are situated: after the pollen has been discharged, the upper parts of the spadix grow warmer, and the lower parts cool gradually upwards.

Experiments made to ascertain the cause of this heat lead to the conclusion that it is attributable to a process of combustion. Saussure found that the flowering spadix of *Arum maculatum* abundantly absorbed oxygen; and Vrolik and De Vriese, comparing the temperatures attained by a spadix placed in oxygen gas and by one placed in common air, found that the former always exceeded the latter, while a spadix kept for a longer time in nitrogen gas did not manifest any increased temperature.

Connected with the subject of the temperature of plants are the interesting observations of Boussingault, Alph. DeCandolle, and others, on the different external temperatures required by different plants to stimulate them into either vegetative or reproductive activity. It is well known that any given plant will require a certain sum of heat during a season to enable it to go through its whole course of development, and that under certain limits the course of development will be passed through proportionately more quickly in warmer climates. Further, it is known that most plants of warm climates are killed by certain degrees of cold. But it is further observed that certain temperatures, insufficient to injure plants, are at the same time insufficient to "start" them into growth, and that different species of plants have different constitutions in this respect; while, on the other hand, excessive temperatures may render plants barren

by over-stimulating vegetative action, as is observed in the Vine in the tropics, and commonly also in badly managed exotics in our hothouses.

Sect. 2. Luminosity.

In most botanical works we find noticed the observation of the daughter of Linnæus, that she perceived a peculiar flashing luminosity of the flowers of *Tropæolum majus* on a hot summer's night—together with a statement that the same appearance has been observed in the orange Lilies, Sunflower, Marigolds, &c. The fact that most physiologists, from Saussure downward, who have sought to repeat these observations have failed, and that the appearance is always assigned to orange or red flowers, leads to the belief that the statements are founded on error, arising from the peculiar effect of these tints upon the eye. The influence upon the eye of the brilliant orange and crimson flowers of some of the Rhododendrons and Azaleas now grown in our gardens is very similar to that of looking upon a luminous body. The asserted luminosity of flowers is certainly at present a very questionable matter. The cases that have been recorded are cases of optical illusion, or in some instances of exudation of inflammable vapour.

Phosphorescence.—On better authority, namely that of Humboldt, Nees von Esenbeck, Unger, and others, rests the fact that the thallus of some Fungi is luminous in the dark. The imperfect thalloid structure described as *Rhizomorpha subterranea*, occasionally met with in mines, exhibits upon its ramified structure points which possess an irregular phosphorescence, sometimes rising to such a degree of luminosity as to enable surrounding objects to be distinguished. According to Unger's observations, the light is not emitted from decaying matter, but from a peculiar superficial layer of cellular tissue. Phosphorescence has been observed in other mycelia, and it is also exhibited in the perfect Fungus of *Agaricus olearius* and other species.

Rotting wood is well known to be often phosphorescent; and some authors state that this does not depend upon the presence of Fungi; but, seeing the proved occurrence of phosphorescence in the mycelium of Fungi, it is most probable that the luminosity is attributable to them, especially as it is removed irrecoverably by drying up the damp rotten wood.

The statement that the Moss *Schistostega osmundacea*, which grows on the roofs of caves, is phosphorescent, has been declared by Milde to be erroneous. We could detect no trace of it in observations made some years ago, and we agree with Milde in attributing the appearance to the glistening caused by the reflections and refractions of light on the wet surface of the cellular leaves.

According to Martius, the milky juice of *Euphorbia phosphorea* becomes luminous when removed from the plants and heated gently.

The fullest details, with illustrations, on the subject of phosphorescence are to be found in the volumes of the 'Gardeners' Chronicle,' 1871, 1872, 1874. Dr. Cooke's paper on the same subject in 'Science Gossip' for 1871 should also be consulted on the subject.

Sect. 3. Movements of Plants.

The absence of the phenomena of motion was formerly imagined to constitute one of the distinguishing characters of plants as contrasted with animals; but, in fact, members of the Vegetable Kingdom not only exhibit partial movements of their internal or external structures, but in some cases the entire organism has the power of locomotion.

Exciting causes.—The movements of different plants are dependent upon very diverse causes, some of them being entirely mechanical, and due to physical affections of the tissues by the conditions of the surrounding atmosphere, and to alternate conditions of turgescence and exhaustion; others are mechanical in appearance, but excited by causes which simple physical laws will not explain; while a third kind depend upon the contractile quality of the protoplasmic substances, which gives rise to automatic movements comparable to those of the lower animals and to the ciliary motion found in particular tissues of the highest animals.

To the first of these classes belong such phenomena as the bursting of seed-vessels, anthers, &c., attributable in part to the hygroscopic conditions of the tissues, which, possessing unequal power of imbibition and unequal elasticity, are torn apart or curved in various ways by unequal contractions and expansions, caused by access or abstraction of moisture. These are cases of what is called in common language "warping," and can scarcely be regarded as vital phenomena, being definite modes of destruction of dead structures, resulting from special structural conditions.

The second class of movements are those exhibited periodically, or under special stimulus, by the external organs of plants, such as the "sleeping" and "waking" of leaves and flowers, and the movement of the Sensitive Plants, &c. To these may perhaps be added the less striking, but not less enigmatical, movements which cause the twining condition of stems &c.

The movements of the third class are those already adverted to in former sections, where the protoplasmic matter of cell-contents, or free bodies, such as zoospores, spermatozoids, or even perfect individuals, such as *Desmidieæ*, Oscillatoriaceæ, exhibit temporary or permanent power of locomotion. Of this character also are the protrusions observed by Mr Francis Darwin of fine threads of protoplasm from the pear-shaped glands of the common Teazel (*Dipsacus*). These threads have the power of contracting strongly, and the contraction is further induced by acids, by induced electric currents, by heat, and other agents.

The *rotation* of the protoplasmic cell-contents (p. 549) doubtless depend upon (imperfectly understood) causes similar to those which render many of the simpler plants locomotive; and the movements exhibit the closest resemblance to those of some of the Protozoa in the Animal Kingdom—in particular, of *Amœba* and its allies. The locomotion of free product

of the cell-contents, such as zoospores and spermatozoids, is generally immediately resultant from the movement of *cilia* existing upon their surface; and the same statement applies to the locomotion of the "cell-families," which form the representatives of species in the Volvocineæ. The locomotion of the Oscillatoriaceæ and Diatomaceæ, however, does not appear to be effected through the agency of cilia; at all events no such structure can be detected with our present means of observation.

The ciliary motion of the unicellular plants and reproductive bodies is, although inexplicable, a more general phenomenon of life than the movement of the Diatomaceæ &c., where these organs are not detected. Some authors incline to regard the motion of Diatomaceæ as dependent upon osmotic currents, resulting from the interchange of matter between the cell-contents and the surrounding water.

Movements from Changes in Hygroscopic State.—Movements of various kinds, more or less mechanical in appearance, take place in the higher plants through the *power of imbibition* and the *elasticity* of their tissues; these movements are generally immediately produced by stimuli of various kinds disturbing the equilibrium in the tissues.

Great difference in the power of imbibition exists in different kinds of cellular tissue—collenchymatous tissue, for example, swelling out when wetted, and contracting when dried, far more than woody structures. Experiments have shown that the degrees of expansion and contraction vary in different plants and tissues of plants in a range from $\frac{1}{1000}$ to $\frac{1}{2}$ the diameter of the cells. In cases of great contraction a wrinkling of the cell-membrane is generally involved.

All living cell-membranes possess a certain degree of elasticity; and consequently a certain amount of difference of dimensions is dependent upon the degree of tension or turgescence of the cell from the presence of fluid contents. Cells in which osmotic processes are going on are constantly in a state of greater or less tension.

The expansion of cellular tissue through turgescence, permitted by the elasticity of the membranes, appears to have a much smaller range than the expansion by simple imbibition. The experiments of Unger and of Brucke give a range of $\frac{1}{80}$ to $\frac{1}{6}$.

It is evident that the elasticity of parenchymatous tissues must be capable of exerting influence on the position, form, and direction of the organs of which they form part. Supposing a tissue to be uniformly developed, its expansion through turgescence need not alter the general form, nor the relative position of the parts; but if unequal endosmose take place in different parts, causing disturbance of the equilibrium of turgescence, curvature and distortion must ensue. Again, if an organ is composed of regions in which the tissues differ in degree of elasticity, it may suffer a disturbance of the equilibrium of turgescence still more readily; and this is probably the cause of most of the automatic movements of organs of plants, as more fully explained under the head of Tension (p. 609).

Dehiscence of Fruits etc.—This is usually the result of a greater degree of turgescence in some cells than in others and ultimate rupture, and it may also be due to irregularity in the process of drying, whereby certain layers contract more forcibly than others. The different anatomical

construction of different layers also promotes the process, as well as the pressure from within of the growing seeds.

The movements of the awn of *Avena sterilis* are in like manner attributable to the possession of two layers of different anatomical and hygroscopical structure. The similar twisting of the awns of other Grasses, the styles of *Erodium*, &c., has been described by Mr. F. Darwin, who, in the 'Linnean Transactions,' has explained the mechanism by which these plants are enabled to bury themselves in the ground.

Irritability.—The equilibrium may be disturbed by various stimuli, mechanical and chemical. When an organ is strikingly affected by mechanical influences, we have the phenomenon of "irritability," such as we see in the Sensitive Plants, *Dionæa*, &c. The "sleep" of plants is doubtless a phenomenon differing only in degree; and this slower movement is probably attributable to the chemical action of light.

Periodic and Induced Movements.—The movements of plants consist for the most part of the curvature or the folding-up of organs; and in such cases the organs are always found to possess certain peculiarities of structure and mode of union to other organs. The movements take place periodically (in consequence of the regular alternations of external influences), or irregularly (from the accidental influence of special stimuli).

Periodical movements are more particularly connected with the influence of heat and light; and their degree is generally more or less proportionate to the intensity of these influences.

Action of Heat and Light.—The sensitiveness and periodic movements of the leaves of the Sensitive Plant are not manifested at a lower temperature than 15° C., while permanent loss of motion and death occur above 52° C.

Exposure to light causes movement in the leaves of Sensitive Plants, raising them from the depressed position they occupied in darkness; and prolonged obscurity induces rigidity and loss of motion. Thus Bert showed that Sensitive Plants kept in the dark lost their sensibility after seven days, and died in twelve days. Under green light the plants died after sixteen days exposure, retaining their sensibility for twelve. Under violet and blue light the plants existed (but did not grow) for three months, and retained their sensibility. In *Pothos scandens* with dilated leaf-stalks jointed to the blade, movements may be seen which are apparently associated with the influence of light; thus on the growing shoot the position of the leaves and leaf-stalks varies according to the direction of the light. In some cases lamina and petiole are in the same plane, at other times at right angles one to the other; and even the petiole is twisted on its own axis, so as to place the two surfaces of the leaf in a more or less vertical position. Every intermediate position may be observed.

Effect of Turgescence.—In the best known Sensitive Plant, *Mimosa pudica*, there is a swelling at the base of the petiole, the cells of which constitute, as it were, two springs acting in contrary directions, so that if the one, from any cause, be paralyzed, the other pushes the leaf in the direction of least resistance. These springs, if they may be so called, are set in action by the rush of fluid creating a turgid state of the one set of cells, and a relatively empty state of the other series. What circumstances regulate the

turgescence are not clearly determined. The spontaneous and induced motions, according to Bert, are differently affected by the same conditions. Bert and Millardet also show that the spontaneous movement in the *Mimosa* is not confined to depression, followed after a period by elevation, as in most cases of plants whose leaves sleep; but the movements in question are more or less continuous, the one alternating with the other. Unlike most plants, the Sensitive Plant raises its leaves at night, and lowers them by day.

Nature of the Movements.—The most common kind of movement is that in which leaves or floral envelopes return to the position which they originally occupied, or close up into the same folds which they exhibited in the buds.

Compound leaves, like those of Leguminosæ for instance, display a simple or compound movement; in the Bean (*Faba vulgaris*) the leaves fold upwards, in *Lupinus* downwards, in *Tamarindus* to the side. In *Amorpha fruticosa* and *Gleditschia triacanthos* the rachis or common petiole of the compound leaves rises or sinks, while the leaflets turn downwards or to the side. In *Mimosa pudica* the leaflets fold together, the partial petioles approach each other, and the rachis or main petiole sinks down. In a species of *Oxalis* the pinnate leaves are folded together in an upward direction, a footfall sufficing to cause the plant to close its leaves (figs. 615, 616).

Fig. 615.

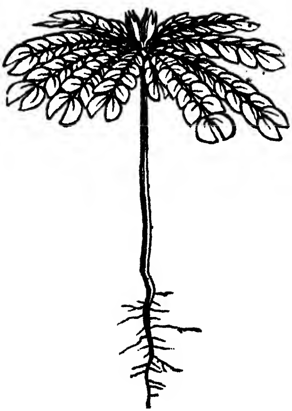


Fig. 616.

Fig. 617.

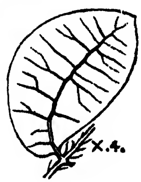


Fig. 615. Plant of *Oxalis*.
Fig. 616. The same species, with the leaves erect and closed, as a consequence of irritation, or in "sleep."
Fig. 617. Leaflet, magnified.

When such movements of leaves or foliaceous organs occur at particular hours, and the structures remain in the new position until the recurrence of a particular period, the closing up is called the *sleep of plants*, which is observed both in green leaves and in the petals of flowers.

The epoch at which the movements take place is very varied. Ordinarily, *leaves* expand in the daylight and close towards evening, while flowers exhibit a great diversity of habit in this respect—so much so, indeed, that Linnæus was enabled to draw up a list of flowers, fancifully termed a "floral clock" (*horologium Floræ*), in which a periodical movement (opening or closing) marked each succeeding hour.

Ipomœa Nil and *Calystegia sepium* open their flowers at 3–4 A.M.; *Tragopogon* at 3–4 A.M., closing again before noon; some *Nymphææ, Nuphar, Lactuca,* &c., about 6 A.M.; *Anagallis arvensis,* 8 A.M. (closing again when the sky is overcast); *Ornithogalum umbellatum,* 11 A.M.; Mesembryanthaceæ generally about 12; *Silene noctiflora, Œnothera biennis, Mirabilis Jalapa,* &c., 5–7 P.M.; *Cereus grandiflorus* &c., *Datura, Mesembryanthemum noctiflorum,* &c., 7–8 P.M.; *Victoria regia* opens for the first time about 6 P.M., and closes in a few hours, then opens again at 6 A.M. the next day, remaining open until the afternoon, when it closes and sinks below the water.

Some closing flowers may be caused to open by exposure to strong artificial light (*Crocus, Gentiana verna*); on others (*Convolvulus*) this has no effect.

In most of the periodical movements the motion is very slow; but certain exceptions to this exist. Thus in the leaves of *Desmodium gyrans* and other species, the *labellum* of *Megaclinium falcatum,* the styles of *Stylidium adnatum,* and others, the movement is quick enough to be directly perceptible.

In *Desmodium gyrans* (the Telegraph-plant) the trifoliolate compound leaf has a large terminal leaflet, and a smaller one on each side. When this plant is exposed to bright sunlight, in a hothouse, the end leaflet stands horizontally, and it falls downward in the evening; but the lateral leaflets move constantly during the heat of the day, advancing edge first towards the end leaflet, and then retreating and moving towards the base of the common petiole, alternately on each side, in a manner very well compared to the movements of the arms of the old semaphore telegraphs. In *Megaclinium falcatum* (Orchidaceæ), when exposed to sufficient heat, the labellum rises and falls slowly in periods of several minutes; this structure is also *irritable,* and moves more quickly, with an oscillatory motion, when touched.

Induced Movements.—Irregular or irritable movements take place in a great variety of plants, of which the following paragraph contains the most striking examples, separately or in association with the spontaneous movements before mentioned. They are influenced by contact and by various chemical agents, while others paralyze the motion:—

Leaves: The "Sensitive Plants" (*Mimosa pudica, sensitiva, casta,* and many other species); *Æschynomene sensitiva, indica, pumila*; *Smithia sensitiva*; *Desmanthus stolonifer, triquetris, lacustris*; *Oxalis sensitiva,* and, in less degree, *Oxalis stricta, Acetosella, corniculata, Deppei,* &c.; *Robinia Pseudoacacia* folds its leaves when violently shaken in the morning; lastly, *Dionæa muscipula,* the Venus's Fly-trap, which folds its leaves when visited by insects, and *Drosera* (fig. 588, p. 560), which enfolds itself over the captured prey.

The *spontaneous* slow movement which occurs at stated periods (movements of sleeping and waking) is, as has been said, different from the sudden motion caused by external stimuli. Ether and other anæsthetics

paralyze the latter, but have no effect on the spontaneous movements. There is no special contractile tissue in these plants.

Petals.—The movements of opening and closing have been alluded to. Other induced movements occur in connexion with fertilization, one of the most striking of which is that of *Pterostylis*, an Australian Orchid, where the lip has a tongue-shaped extremity covered with hairs and a hinge-joint in the middle. If an insect alight on the tongue, the tip bends upwards in such a manner as to imprison the insect, and fix it up against the anther till he has removed the pollen. See also *Drakea*, fig. 462, p. 372.

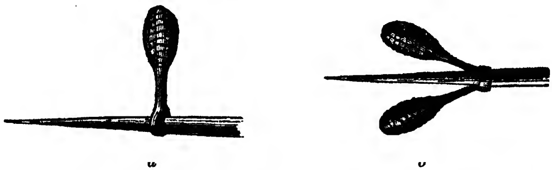
Stamens—curving towards or away from the stigma and dehiscing when touched: *Berberis vulgaris* and other species, *Parietaria judaica*, *Sparmannia africana*, *Cereus grandiflorus*, *Helianthemum vulgare* and other species, and various plants of the tribe *Cynareæ*. Other curious movements of the stamens and pistils, and also of the staminodes, are alluded to under the head of Fertilization. Heckel attributes the movements of the stamens of *Berberis* to the alternate changes of form, now long, now short, in the constituent cells of the stamens. In order to verify this, M. Heckel availed himself of anæsthetics. The necessity for doing this arises from the fact that immediately the stamens are cut, in order to take from them a slice to examine under the microscope, contraction is caused; but by, so to speak, paralyzing the cells, a section may be taken, and the normal unirritated condition of the cells ascertained. So treated, longitudinal slices of the irritable part of the stamen (the concave inner surface in this instance) are seen, according to M. Heckel, to be arranged in parallel rows, and each cell to be longer than it is wide, its yellow contents being diffused throughout the cavity and applied to the walls. An examination of the same cells in the excited or irritable state shows that they become shortened, contracted, and gathered together till they only occupy two thirds of their original space; the contents of each individual cell are collected together in the centre of the cavity, and the outer cell-wall or envelope is thrown into transverse ridges. So, then, in the one case the cell is at rest, in the other it is tense and contracted, the seat of contraction being in the protoplasm lining the interior of the cell-walls, rather than in the cell-wall itself.

The opposite convex surface of the same stamen, with which an insect visiting the flower does not come in contact, is not sensitive to external impressions of this character, though it also shows contractile power arising from internal causes. This contraction is exercised in a manner directly contrary to that manifested by the cells on the inner surface—that is to say, that when in a state of rest, under the influence of the chloroform, they are contracted, while after irritation they are distended. They would thus have the effect of pulling the stamen back into its old position after irritation.

The peculiar movements of the pollen-masses of Orchids have already been alluded to (p. 373). Another illustration from *Orchis pyramidalis* may here be given. In this plant the two caudicles of the pollen-masses are connected together by a saddle-shaped disk, the pollen-masses when in the anther being nearly vertical in direction and parallel one to the other. When removed from the anther by the proboscis of an insect or the point of a needle (fig. 618, *a*) the saddle-like disk contracts so as to attach the

pollen-mass to the needle &c. Then occurs, first a divergence of the two pollen-masses one from the other, and subsequently a depression, so that they assume a nearly horizontal direction (fig. 618, *b*). In this position they

Fig. 618.



Orchis pyramidalis: *a*, pollen-mass just removed from the anther, vertical; *b*, pollen-masses divergent and horizontal.

are so placed as to come into contact with the V-like stigmata of another flower, and thus effect cross-fertilization.

Style: *Goldfussia anisophylla*, *Martynia*, *Mimulus*, &c.

Movements of Stems.—Some plants manifest a series of spontaneous movements, as *Ceratophyllum*, where the stem exhibits regularly movements of bending and straightening. The young growing shoot of *Abies Nordmanniana* has been observed to revolve irrespectively of the sun's movements, and the terminal shoots of the Deodar have similar movements.

Climbing Plants.—The phenomena of the movements of climbing plants, including the spontaneous revolving movement of tendrils &c., and those dependent on contact, have been studied in detail by Mr. Darwin, who has shown that organs of the most diverse morphological character may nevertheless exhibit the same phenomena. The object is to enable the plant to expose its leaves to the light and air with little expenditure of material. In this way a weakly growing plant can maintain itself in the struggle with trees and vigorous growing plants. Darwin divides climbing plants into four classes:—1, those that twine spirally in a dextrorse or sinistrorse manner round a support; 2, those endowed with irritable organs which when they touch any object clasp it; 3, plants climbing by means of hooks, as some Palms, Brambles, &c.; 4, plants climbing by means of rootlets, as the Ivy.

The two first Classes exhibit special movements. The young growing shoots of climbing plants, and, as we have seen, of Conifers and probably most other plants, if watched for a continuous period, or observed at intervals, may be observed to bend to one side, and to travel slowly round to all points of the compass in succession, the revolving movement, which goes on by night as well as by day, varying in rapidity according to circumstances and ultimately ceasing. The revolution is effected by a bending over of the stem first in one direction, then in another, so that the revolving stem sweeps round, but does not become twisted so long as it is

free at the tip. If, during the course of its revolutions, it come in contact with any object, such as a stem or a branch of another plant, it twines around it. The cause of the movement is supposed to be due to rapid growth in a longitudinal direction, the band of growth travelling round the tendril and successively bowing each part to the opposite side.

Leaf-climbers.—These are plants whose leaf-stalks clasp round any support that may come in their way, while, in other cases, the plants climb by the tips of their leaves, as in *Gloriosa*, p. 56 (fig. 67). The young internodes of these plants revolve as in the former case, and with the object of bringing the petioles into contact with surrounding objects. The petioles in these cases are, when young, sensitive to a slight touch, bending towards the touched side at different rates in different species. Such petioles after a few days become much thickened, and assume a stem-like character.

Tendrils are thread-like modifications of leaves, peduncles, or branches, possessing the power of spontaneous revolution, the whole length of the organ exhibiting curvature except at the extreme tip, which is sensitive to touch on one side or the other, or on both. When the end has caught a support, the tendril winds round it in a spiral direction according to the position of the support and the side first touched. Twining plants, on the other hand, curl round their supports invariably in the direction of their revolving movement. The tendrils of different species of the same genus twine in different manners—in some cases bending themselves away from the light, so as to seek crevices in the bark, rocks, or walls on which they are growing, and often developing adhesive disks at their extremities, as in *Ampelopsis tricuspidata* (*Veitchii*). The different movements executed by tendrils may be referred to revolving nutation, bending to or from the light and in opposition to gravity, in addition to those caused by a touch, and spiral contraction; and it seems probable that the inducing causes may be different. Some are probably due, as stated by Sachs and De Vries, to rapid growth along one side; but Darwin doubts whether the movements consequent on a touch can be so caused. The first action of a tendril, says Darwin, is to place itself in a proper position so as to be in the most favourable position for catching hold of any support. Another wonderful property is the way in which they generally avoid coiling themselves around the stem from which they themselves proceed. When, says Asa Gray, "a tendril sweeping horizontally comes round so that its base nears the parent stem rising above it, it stops short, rises stiffly upright, moves on in this position until it passes by the stem, then rapidly comes down again to the horizontal position, and moves on so until it again approaches and again avoids the impending obstacle."

Of the two kinds of motion, the spontaneous revolutions and that induced by contact, the former may be compared with the spontaneous movements of the leaflets of *Desmodium*, or the sleep-movements of leaves, while the movements due to contact are analogous with the induced movements of the sensitive plants. The tendrils of *Passiflora gracilis* and of a gourd have been seen by Gray and others to coil up rapidly and perceptibly when their extremities are gently rubbed, straightening again after a short time, to be recoiled if again excited. Once a grasp has been obtained the sensibility ceases.

PART IV.

GEOGRAPHICAL

AND

GEOLOGICAL BOTANY.

CHAPTER I.

GENERAL CONSIDERATIONS.

The object of this department of Botany is to determine the laws which rule over the Distribution of Plants in Time and Space. This abstract study is founded upon the facts furnished by Botanical Geography and Geology, or the description of the present and past conditions of the Vegetable inhabitants of the globe, and, in return, supplies those branches of practical inquiry with principles by means of which they may be systematized.

Botanical Geography, which undertakes the description of the peculiarities of the vegetation occurring at present upon the earth's surface, and *Botanical Geology*, which pursues the investigation of the conditions of vegetation which have successively existed in different Geological epochs, deal with facts so far distinct in their character that it is most convenient to treat of them separately; but the *principles* are common to both, and may be taken as one subject.

Explanations of the facts which are obtained by geological inquiries can only be securely founded, either directly or indirectly, upon laws derived from facts furnished by experience of existing phenomena; hence the principles laid down in the present chapter are for the most part only actually valid in relation to existing conditions, and, the subject yet being in its infancy, are mostly only speculatively applied to the elucidation of geological phenomena.

Sect. 1. Influence of External Agents upon Vegetation.

Climate.—Plants are endowed with means of diffusing themselves, more or less efficiently in different cases, over the surface of the globe; but in most cases their existence is limited to certain regions or countries. Geographical obstacles, such as seas,

mountains, desert tracts, prevent their spreading indefinitely: some of these may be overcome by accidental influences, such as seas intervening between countries, and the like; others can neither be conquered nor evaded, such as *climate*, which fixes unalterable limits to the stations which can be permanently occupied by species.

That Cold and Heat, Damp and Drought, intensity and duration of Light, the chief constituents of what we call Climate, are the most important of the external influences acting upon plants, is a fact manifest not merely from the conclusions at which we have arrived in the study of Vegetable Physiology, but one which is revealed by the most slender experience of horticulture and the most superficial acquaintance with physical geography.

The nature of the soil doubtless has also much influence on the distribution of plants, dependent less, probably, on its chemical composition than on its mechanical constitution and hygrometric state.

Every species of plant flourishes best within a certain range of temperature, beyond which, on both sides, it either suffers from summer heat or is killed by winter cold.

If the earth's surface were of uniform character, we might expect to find forms of vegetation arranged in bands or zones succeeding each other from the equator toward the poles, each occupied by plants "hardier" than those of its equatorial neighbour. Such zones of vegetation have in fact been laid down by botanical geographers. Meyen drew up a plan, in which a number of zones were marked, defined on each side by lines passing round the earth at certain parallels of latitude, between which a certain average climate was assumed to exist.

Isothermal Lines.—From the want of uniformity of the surface of the globe, the *isothermal lines, i. e.* lines passing through spots which have an equal annual temperature, by no means correspond to parallels of latitude—the distribution of land and sea, and the alternation of plains and mountains, deflecting such lines to the north and south, sometimes to a very great extent. In addition to this, from the diversity of habit of plants, they are differently affected by heat and cold, and the distribution of species is far more influenced by the *summer* and *winter* temperature than by the entire amount of heat received during the year.

Nevertheless, as a general rule, plants have a *polar* and an *equatorial* limit, fixed by temperature.

Temperature as regards plants may be divided into useful, useless, and injurious or destructive. Each plant, as we have seen, requires a certain sum of heat to live, so much more to flower, more still to ripen its fruit, &c. Within certain limits it is immaterial whether the plant get this heat in a short period or diffused over a longer time. Temperatures below 0° C. are useless to most plants (that is to say, vegetative action is

arrested); but many survive at a much lower temperature. Every plant has a zero of its own, beyond which it does not thrive.

M. de Candolle divides plants, in their relation to temperature, into:—1. *Macrotherms*, or plants requiring much heat, as the plants of intertropical regions; 2. *Mesotherms*, plants of the subtropical and warm temperate zones, subject to great heats and never for any length of time to frost; 3. *Meiotherms*, or plants characteristic of the cool temperate zones; and 4. *Microtherms*, or alpine or arctic plants capable of existing in very cold regions.

The effect of temperature on plants depends very greatly upon their habit: thus annuals which accomplish their life functions in a few months are indifferent to the winter's cold if there is heat enough to enable them to ripen their seed before the winter comes on. Other plants are prevented from spreading from warm latitudes to colder by deficient summer heat: hence a division of plants into heat lovers (*Philotherms*) and cold fearers (*Frigofuges*).

Altitude.—An important qualification arises from the existence of high mountains within temperate and tropical latitudes. The temperature of the soil and atmosphere diminishes with the degree of elevation above the surface of the ocean; and a succession of limits are found upon the sides of high mountains comparable, and in a great degree proportional, to the polar and equatorial limits of plants. Mountains situated in the tropics possess zones of climate which, at successive elevations, resemble horizontal zones situated between the base of the mountains and the poles.

Drought and Moisture.—Moisture and drought are only to be called secondary climatal influences, from the circumstance that they depend in a great measure upon temperature, either directly or indirectly. In the Arctic regions and upon mountain-tops, covered with eternal snow, there is drought from the solidification of the water. In temperate and tropical regions the degree of humidity is dependent not merely upon temperature, but upon this combined with the configuration of the surface of the earth and the nature of the soil. Wherever the temperature of the atmosphere is above the freezing-point of water, it takes up aqueous vapour: even ice evaporates in warm air; and water evaporates in proportion to the temperature to which it is exposed.

The ocean, especially in warm latitudes, gives up vast quantities of aqueous vapour to the atmosphere, which it delivers in very various ways to the land regions. Islands and coasts in general have a moist climate, while the interior of continents is dry; but these rules are interfered with by currents or prevailing winds, carrying air loaded with moisture in particular directions. As an example of this, we find the west coast of Europe with a much damper climate than the opposite east coast of America, owing to the Gulf-stream and the winds bringing the moisture of the West-Indian Sea in a north-west current on to our coast. On the contrary, the prevailing winds blow off the west coast of North Africa, and those received on the north-east side come from over dry land, whence a vast tract of land lying in this continent becomes an arid desert.

There is a great difference also between mountainous and flat countries. The cold upper regions of tropical mountains arrest the prevailing currents of air and precipitate the moisture which they contain. Hence the tracts

at the foot of mountains are well supplied with moisture if the altitude is sufficient, as at the south slope of the Himalayas and the east slope of the Andes. Ætna, which does not reach the line of perpetual snow in Europe, has arid and barren slopes in the upper regions.

Habit in relation to Moisture.—Plants are divided into *Xerophiles*, or those capable of existing in very dry climates; *Hygrophiles*, or those which can only exist in the presence of abundant moisture; an intermediate group is called *Noterophile*. *Xerophiles* are frequently marked by structural characters, such as the succulent tissues encased within a thick leathery rind which admits of little transpiration, *Sedum*, *Cactus*, &c.

The presence of bulbs or of thick stocks and large rigid or fleshy leaves is another characteristic of drought-resisting plants. Another characteristic type of vegetation in such districts is that represented by dry, much-branched spiny trees or shrubs with scanty foliage and small leaves. Resinous exudations, dotted leaves, dense covering of hairs, are other structural peculiarities characteristic of plants of dry regions. Such variations in "habit" are common to most natural orders, and are indications, not of genetic relationship, but of adaptation to circumstances: thus Cacti and Euphorbias have often the same "habit," because living under similar conditions, but, genetically, they are very wide apart. A complete account of this branch of the subject would require a volume for itself.

Of all the influences to which plants are exposed, climate is the most important; it sets absolute limits to species, which is not the case with any other of the causes affecting distribution.

Secondary Natural Influences.

There is no doubt that the distribution of plants is greatly affected by the conveyance of seeds, fruits, &c. from place to place within the same climatal region, by marine currents, rivers, winds, &c., and by animals, especially birds.

Currents.—An example of diffusion by marine currents is furnished by the occurence of the Cocoa-nut Palm fringing the islands of the Pacific; and it is probable that the mixed vegetation of many islands is to be accounted for in part by such causes. Marine currents are of most importance when they pass along coasts, or across tracts of ocean in similar latitudes—such as that part of the Gulf-stream running in the Mexican Gulf, the currents running from Madeira to the Canaries, from the last to Senegal, the east-to-west current of the Society Islands, &c. The seeds of *Guilandina Bonduc*, a West-Indian tree, have been found in a germinating condition on the Cornish coast, where, however, the climate is not sufficiently favourable for it to establish itself. Rivers are most influential when they flow from the east or west. Currents of any kind passing northwards or southwards are less likely to convey seeds &c. into a suitable climate for their naturalization.

Winds.—The winds do not appear to be very influential in transporting Phanerogamous plants; but the cosmopolitan distribution of the Cryptogams is at least partially attributable to the facility with which their microscopic spores are carried away by currents of air.

Icebergs, Glaciers.—Icebergs probably have some share in diffusing plants, since they are often found loaded with masses of earth containing seeds, which they occasionally cast upon strange shores. There is reason to believe that this kind of influence was far more actively at work in North Europe in the geological period preceding the present.

Animals, &c.—The transport by animals takes place partly through migrating birds, partly by quadrupeds which have wandering habits. Among birds, many of the omnivorous kinds (for instance the Thrushes) migrate from north to south in autumn, at the time when berries and similar fruits are ripe, and they often void the seeds of these fruits little altered. Animals which, like the northern Reindeers and Buffaloes &c. of other lands, travel from place to place in troops in search of food, doubtless often carry seeds and fruits adhering to their fur into new localities. Flocks of animals transported through human agency become more fruitful sources of this influence.

Animals may likewise greatly affect vegetation in the way of limitation. The invasion of a region by flocks of graminivorous quadrupeds, the sudden appearance of plagues of locusts or any other of the numerous insect enemies of vegetable life, may quite change the character of the vegetation of a district, somewhat in the manner in which a totally different assemblage of plants springs up on the ground cleared by burning the primæval forests of South America.

Effects of Human Interference.

Migrations.—The results of the activity of man display themselves in both extensions and limitations of the distribution of species.

From the time of the earliest migrations of the human race, certain plants must have been in a condition of constantly increasing diffusion. The native countries of our Cereal grains are not satisfactorily known: they have been or are cultivated wherever they will grow in Europe and the adjoining parts of the other continents. Doubtless many of what we call *weeds* have shared in the transport of the seeds of useful plants, having been either mixed with them or accidently adherent to the clothes, goods, or domesticated animals of the wandering races.

Transport of this kind would be still more active as agriculture extended; and wars, the improvement of navigation, the discovery of the New World, and countless minor events contributed to increase the interchange of the natural products of different regions, either intentionally or by accident.

Cultivation, &c.—Systematic cultivation of land is peculiarly favourable to the intermixture of new elements in the floras of particular regions, from the fact that *seeds* of many *varieties* of useful plants are constantly imported from climates where they ripen better or can be kept more easily at a higher standard of excellence.

Clover-seed, for instance, is largely imported into Britain from France and Germany; many of the weeds of our arable lands have doubtless been introduced with foreign seed, such as *Adonis autumnalis*, *Veronica Buxbaumii*, *Papaver somniferum*, &c. Ballast-heaps at sea-ports, where vessels returning home from foreign countries discharge their ballast, have become frequent sources of new importations; and merchandise, such as cotton, but especially seeds, fruits, dye-stuffs, &c., often contains seeds of plants, some of which now and then acquire a footing.

Horticulture is so evidently one of the most important influences in the diffusion of plants, that it is scarcely requisite to dwell upon it.

Extermination of Plants.—On the other hand, human industry has a great tendency to exterminate particular forms of vegetation, or, at least, to greatly affect their relative predominance in a given region. The destruction of forests for the purpose of clearing land for cultivation changes the whole face of vegetation, and even, to some extent, affects the local climate, as also do drainage operations in their degree. Instances of change of this kind might be furnished from almost every part of the globe. North Europe was clothed in earlier times of the present period with dense forests, long since cleared away to give place to cultivated plants and a multitude of wild plants suited to the different conditions of the soil. The forests of North America are, in like manner, disappearing by degrees under the hand of man.

The change is not merely one kept up by a continual effort of cultivation; the original vegetation does not always reestablish itself when the region is deserted. New kinds of plants spread over the cleared ground, and new animal inhabitants come to check the efforts of the old forests to renew themselves.

Sect. 2. Influence of the Laws of Development of :

Plants of Wide Distribution.—If we leave out of view the question of the origin or creation of plants, there is no reason why any given species should not exist in all places where the climate is suitable.

Some kinds of plants are, indeed, very widely spread over the surface of the globe. Hooker has enumerated upwards of 30 species of Flowering plants common to Northern Europe and the Antarctic regions. A considerable number of North-European species extend round the globe in northern latitudes, in the colder parts of North America and Asia. Not a few of our plants occur also on the Himalayan Mountains. *Epilobium tetragonum*, a British species, is found in Canada and in Tierra del Fuego. Our white Hedge-Convolvulus, with some other British plants, occurs in the Galapagos Islands. Many of the Falkland-Island plants are met with also in Iceland. *Plantago maritima*, a common sea-side plant with us, is found at the Cape of Good Hope and at the southern extremity of America.

Representatives of some few natural orders occur in all regions, *e. g.* Compositæ, Leguminosæ, Cyperaceæ, Filices, Equisetaceæ, and a few others. A few genera also, such as *Senecio*, *Rubus*, *Plantago*, *Oxalis*, have also representatives in all regions. Very few species are thorougly cos-

mopolitan, some water-weeds (*Potamogeton*) are nearly so; Shepherd's purse (*Capsella bursa pastoris*) is another instance. Many of the macrotherms are common to the tropics of both hemispheres, the meiotherms and mesotherms are less cosmopolitan.

Instances, however, of such cosmopolitan plants are exceptions to the rule, and the majority of the plants occurring over wide extents of the globe present characters which facilitate their diffusion by natural or artificial influences.

The plants (Phanerogamia) occupying even one third of the earth's surface are but a small fraction of known plants. Many of these are aquatic or subaquatic plants; and a considerable number belong to the list of weeds which accompany man, growing in cultivated land or rubbish &c.; few or no woody plants occur in the lists hitherto published.

It is observable that those cosmopolitan species which occur widely spread over two continents are found also in the adjacent islands.

The Arctic plants occurring in the continents of the Old and New World are found also in the Faroes, Iceland, and the Aleutian Islands.

Plants of Restricted Distribution.—On the other hand, certain plants occur only within very narrow limits; this is the case with many continental species, but more particularly with insular plants, as mentioned in a subsequent paragraph under the head of *insular floras.*

Area of Distribution.—Generally speaking, the species of plants of a continent are found most abundantly over a particular more or less extensive tract, growing scarcer, more or less suddenly, at the margins of this space. Such a space, called the *area* of distribution of the species, in these cases exhibits a *centre* or point of greatest intensity of occurrence.

The areas of many plants extend not only over continents, but over detached islands, and even to other continents. In many instances species are spread interruptedly over their area, as is the case with the alpine plants common to Norway, Scotland, and the Alps, &c.

Representative Species.—It is usual to find the maximum of a species in one country, forming a single centre; and this same species does not recur again with a centre in a distant spot with a similar climate and soil. But *representative species* of the same genus occur not unfrequently under such circumstances; and this is still more the case with genera of particular Orders, sometimes also with the Orders of like habit.

Thus, the Violets of Europe and those of North America are distinct; the dwarf Palm, *Chamærops humilis*, of Europe, is represented by *C.*

Palmetto in North America. The Heaths (*Erica*) of Europe are represented by different species at the Cape of Good Hope. The East and West Indies and Africa have their peculiar Palmaceæ, Zingiberaceæ, Marantaceæ, &c. The succulent Cactaceæ of Central America represent the fleshy Euphorbiaceæ, Asclepiadaceæ, and Mesembryanthaceæ of Africa. The Cape Heaths are represented in Australia by Epacridaceæ, associated in like manner with Myrtaceæ and Proteaceæ. The Firs of the southern hemisphere belong to genera distinct from those of the northern hemisphere, &c.

Specific Centres.—The evident absence of a constant relation between the existence of certain climatal conditions and the occurrence of particular species of plants—still more, the existence of limited *areas* of distribution, often exhibiting *centres* of greatest abundance—have led to the supposition that the individual species of plants have been created at particular centres, whence they have spread themselves over more or less extensive tracts, in the course of their extension becoming intermixed with other species, and thus producing complex assemblages.

The spreading of what are called social plants, such as Pasture-Grasses, Furze, various forest-trees, &c., illustrates the facility with which many plants extend themselves over new ground. The *Anacharis*, a North-American water-plant, has been diffused all over England within the last few years. The diffusion of certain plants is also greatly dependent on the success of some plants over others in the struggle for existence which is ever going on in nature. It does not follow that the wild plants in any given area are those which are best adapted for that situation. They are often the weakest, and are overpowered by other plants. In this way native vegetation constantly gets exterminated by foreign intruders.

In this hypothesis it is unimportant whether we imagine a single plant (or pair of diœcious plants) or a more or less extensive assemblage of individuals to have been created on the same spot. This is a question impossible to be solved by science.

Some authors believe that species have been created at many points where the conditions were fitting, explaining in this way the interrupted areas of certain plants.

Successive Creation of Species.—The facts revealed by Geology, as well as by Botany itself, tend to prove that the creation of species has not been simultaneous, but *successive*, in different geological periods. Not only do we find in the older formations fossil plants different from living vegetation, but those beds immediately preceding the present surface of the earth contain not only remains of animals of existing species, but fossil plants closely resembling, if not identical with, existing plants.

Existing Agencies not sufficient to account for Plant-distribution.—Numerous cases of scattered distribution of existing

vegetation cannot be explained by reference to existing influences, such as transport, &c. Thus species with large seeds grow in countries between which apparently insuperable obstructions to transport exist; many species are common solely to the tops of very distant mountains; many widely distributed aquatic plants produce seeds which sink to the bottom of the water when ripe, &c.

Again, species are wanting in regions so well adapted to their existence that, when artificially introduced, they establish themselves like natives. Certain countries, separated by broad oceans, have more species in common than either the distance or nature of their climate would render probable under ordinary circumstances; while contiguous countries, with similar climates, sometimes present very different species.

Some countries are remarkable for a great number of species in a given area, others for paucity of species.

Lastly, species of simple structure (Rushes, Grasses, &c.) have often wide range, even though their seeds are not more easy of transport than usual, while others of higher organization, with seeds or fruits easily transported (Compositæ, &c.) often occur in very limited areas.

To sum up these statements, the occurrence of certain species, as a general rule, in one region rather than another, their abundance in particular localities, the extension and especially the disjunction of species destitute of efficient means of transport, the non-extension, on the contrary, of species possessing seeds easy of transport, certain analogies and certain differences between the floras of several countries, and their relative richness in distinct forms—all these important phenomena are inexplicable by causes now in active operation; and we are consequently led to seek their solution by the aid of geological inquiries.

The late Edward Forbes was the first to open this line of inquiry, in a most acute and ingenious Essay on the Origin of the existing Flora of Britain. Hooker has pursued the same line of reasoning in his inquiries into the botanical geography of the southern hemisphere.

Sect. 3. Geological Influences.

Natural Science is incapable of elucidating the actual origin or creation of organic beings; but it seeks to trace up, as nearly as possible, to the earliest periods the phenomena exhibited by created things or beings, and the successive and gradual evolution of forms according to the laws of variation, the influence of vital competition and external conditions, as previously mentioned. In addition, the botanist seeks, by geographical and geological in-

quiries, to discover the probable aboriginal localities of species of plants.

It is impossible to say in what part of the globe plants first appeared. Probably they grew on lands now submerged beneath the ocean, or, still more likely, they were perishable aquatic plants which have left no trace of their existence. Geology teaches that the dry land of the globe has been successively elevated and depressed below the surface of the sea at various epochs since plants were first created; hence there have existed successive and variable centres of creation. There may have existed means of communication between different centres, so that species may have passed over from one to another, and in this way survived in a new locality the destruction of their birthplace.

Species have made their appearance successively during different geological epochs, and have had more or less extended duration.

Probably most of our existing species date from an epoch anterior to that at which the existing continents acquired their present configuration. A large proportion of the present genera were in existence before the end of the Secondary period.

They may have spread widely in ancient times, and their area may have been broken up subsequently by obstacles now insurmountable. They may have been transported in past ages by causes not now in operation.

Thus the disjunction of certain alpine and arctic species, that of aquatic or marsh-plants in different countries, that of large-seeded plants in islands and more or less distant continents, may be explained by their antiquity or former wide diffusion, as well as by supposing creation at various points.

The species at present confined within small areas, in spite of means of transport or continuity of land and suitable climate, would appear to be those of most recent creation; that is, they seem to have originated since the existing continents were formed. Widely spread species, on the other hand, which are difficult of transport are probably the most ancient.

In the comparison of successive geological formations, it appears that the earliest plants were chiefly species of simple organization and few in number—and that by degrees more highly organized plants were added and replaced many of the earlier ones, which perished. In existing vegetation the simpler kinds seem to be the most ancient, and those of more complex structure more recent, judging from the wider diffusion of the former than the latter.

Ligneous plants established themselves in northern and temperate countries at an epoch when the climate must have been more humid and more cloudy than at present. At the present time, regions in the South of Europe, North Africa, the Canaries, the Southern United States, and

elsewhere once cleared and exposed to the influence of the sun, do not become clothed again by forests such as they possessed formerly. Coniferæ and Amentaceous plants, which form the chief constituents of forests in these regions, are Phanerogams of low organization. Their probable antiquity, judging from their occurrence in masses in certain countries, confirms the view that existing species are of unequal antiquity, and that the older species are of lower type.

The facts of existing Botanical Geography are in general clear and concordant, if we suppose that the most ancient species of Phanerogams comprise the majority of plants either aquatic or loving moisture, then many northern and alpine plants and most of the trees of our temperate regions. We may suppose at the same time that the most recent species occur principally among the plants of warm regions, among the Dicotyledons with an inferior ovary and a gamopetalous corolla (such as Compositæ, Dipsaceæ, Campanulaceæ, &c.) and among the other Phanerogams with structure complicated in other respects (such as Orchidaceæ, Palmaceæ, Apocynaceæ, Asclepiadaceæ, Cucurbitaceæ, Passifloraceæ, Begoniaceæ, &c.).

(The considerations stated in this Section are derived, with slight modifications, from the 'Géographie Botanique' of Alph. De Candolle, a most important general work on this subject, which should be studied by all those who are interested in these questions. Lyell's 'Principles of Geology,' vol. ii. Book iii., and Darwin's 'Origin of Species' should also be consulted, and for a brief summary Mr. Baker's 'Elementary Lessons on Botanical Geography.')

CHAPTER II.

BOTANICAL GEOGRAPHY.

Sect. 1. Distribution of Plants in Climatal Zones between the Equator and the Poles.

The description of the actual conditions of vegetation on the surface of the globe is a subject embracing a vast amount of facts, which are not only capable of being considered under many different points of view, but in many respects offer at present only fragmentary materials for establishing principles. In the present work, where only a limited space can be allotted to this department, it is necessary to confine ourselves to a few of the principal generalizations, calculated to give an insight into the characters of the study, but confessedly very imperfect as representations of the natural phenomena with which it deals.

Climatal Zones.—In the preceding Chapter we have seen that climate has a most important influence upon vegetation; and proceeding on this ground, it is possible to divide the surface into climatal zones, within which a certain average character of vegetation exists. But mere temperature is but one of the influences; and it is evident that many diverse conditions must exist within such climatal zones, dependent upon the other influences above referred to. Hence, although the general views afforded by marking out climatal regions are useful to the beginner, it is necessary to bear in mind that they are essentially superficial. In Meyen's subdivision of the globe, the zones were defined by parallels of latitude; but the distribution of temperature, the chief agent here regarded, is so irrelative to the parallels, especially in the northern hemisphere, that we have modified them by *isothermal* lines obtained from Dove's maps. The isotherms selected are mostly annual temperatures; but in defining the Arctic regions it has appeared more natural to take the line indicating an equal temperature in the months of September and July.

In the following summary the names of Meyen's zones are retained; the peculiar limitation by isothermal lines is indicated for each zone.

1. *The Equatorial Zone.*—This zone, as limited by us, comprehends but a comparatively small range in the New World, and is most developed in the Old, especially in Africa. On consulting an isothermal map, it will be observed also that the larger portion of it lies on the north side of the equator, since the preponderance of land in the northern hemisphere deflects the isothermal lines in this direction. The boundaries are the annual isotherms of 79°·3 F. (26° C.) on each side of the equator; but it may be noticed that in Africa, as well as in Hindostan and in the Indian archipelago, there exist between these lines circumscribed regions in which the annual isotherms rise to 81°·5 F. (27° C.).

The characteristics of this zone are marked by the extreme luxuriance of vegetation, from the great heat, together with the abundant moisture. The trunks of the trees attain enormous diameter; the flowers have most brilliant colours; and not only is the earth clothed most profusely with numberless forms of plants, but the trees are overgrown by Orchids, Aroids, Bromeliaceæ, and Ferns, and matted together by *Lianes*, or gigantic rope-like woody climbers; so that the *primæval forests* present such a dense mass of vegetation as to be almost impenetrable, even to the explorer who advances axe in hand. The Palms, the Banana tribe (Musaceæ), arborescent Grasses, *Pandanus*, Scitamineæ, and Orchideæ are very striking features; the Fig-trees of most varied kinds, the Silk-Cotton-trees (Bombaceæ) also abound both in the Old and New Worlds; the Cæsalpiniæ, Malpighiaceæ, Anacardiaceæ, Swieteniæ, Anoneæ, Bertholletiæ, and Lecythideæ especially mark the forests of America; the Sapindaceæ, Artocarpi, Sterculiaceæ, Ebenaceæ, Meliaceæ, Laurineæ, &c. those of the Old World. In this zone also, in the Indian archipelago, occurs the most remarkable of the Rhizanths, the gigantic parasite

Rafflesia, with its flowers 3 feet in diameter; while in America this is almost rivalled by the Victoria Water-lily, and the Aristolochias with their enormous helmet-like flowers—said, indeed, to be worn in sport as caps by the Indian boys.

Rich as the vegetation of this zone is in general, we find within the limits some of the poorest tracts upon the globe—namely, where water is wanting. The African desert and a portion of Arabia are the most striking examples; but the llanos of Venezuela are scarcely less parched and lifeless during the dry season, and in the rainy season present only grassy plains like the steppes of Central Asia. The poverty of these tracts is accounted for by their peculiar position, cutting them off from the influence of moist currents of air, their natural waterless condition being of course dependent on the geological changes which gave them their present configuration.

2. *The Tropical Zones.*—These extend, in the north and south hemispheres, from the boundaries of the equatorial zone, at the isotherms of 79°·3 F. (26° C.), to the isotherms of 72°·5 F. (22° C.). Taken altogether, the characteristics of these zones, as might be expected, are closely allied to those of the preceding. Rio de Janeiro and Canton are cited by Meyen as instances of this resemblance; Palms, Bananas, Cannaceæ, Meliaceæ, Anonaceæ, and Sapindaceæ prevail (in humid districts) here, and Orchids, Pothos-like plants, and *Lianes* abound. The Tree-Ferns, the Pepper-plants, Melastomaceæ, and Convolvulaceæ, however, become more prominent here, and serve as distinctive characters; and it is stated that, in these zones, the forests exhibit fewer parasites and more underwood. That portion of the western coast of South America lying within the south tropical zone forms an exception to the general rule of luxuriance of vegetation, as does the inland tract of Africa bordering on the equatorial zone.

3. *The Subtropical Zones.*—These are bounded on the equatorial side by the annual isotherm of 72°·5 F. (22° C.), and towards the poles by the isotherms of 68° F. (20° C.). The countries lying within these enjoy the most delightful climates on the globe. Though the summer heat never rises to the intense heat of the torrid zone, it suffices to ripen most of the tropical fruits; while the winters are so mild that vegetation is never arrested. Palms and Bananas are still met with in the plains, and arborescent Grasses form a feature of the landscape, both in America and Asia; but the most striking character of these regions is formed by the abundance of forest-trees having broad, leathery, and shining leaves, such as the Magnolias and the Lauraceæ, and also of the plants of the Myrtle tribe. Proteaceæ, Acacias, and Heaths attain their maximum development.

4. *The Warmer Temperate Zones.*—Equatorial boundaries, the annual isotherms of 68° F. (20° C.); polar boundaries, the isotherms of 54°·5 F. (say 12° C.). The general characteristics of these zones arise from the combination of the shining, leathery-leaved trees of the subtropical zones with the forest-trees which we find in our own country, such as Oaks, Beeches, &c.; the Palms vanish; but a number of handsome evergreen shrubs present themselves, and Heaths, Cisti, and showy Leguminous plants are very abundant. The countries lying within these zones in

different parts of the globe differ a good deal in their vegetation, and we may therefore enter into rather more detail here.

In the Mediterranean region evergreen dicotyledonous trees with glossy leaves, showy shrubs, and many bright-coloured bulbous plants abound; *Erica arborea*, the Bay, and the Myrtle are characteristic; the Turkey, Holm, and Cork Oaks, the Chestnut, the Strawberry-tree, with the Cherry-Laurel, Laurustinus, and Pomegranate are frequent, as are also the Phillyreæ, Rosemary, Oleander, &c.

The Vine is a native of this zone, and is said to attain a diameter of 3 to 6 inches, and to climb to the top of the highest trees in the forests of Mingrelia and Imeritia. The barren tableland of Asia falls in this zone, as does Japan, which has a rich vegetation. In America are found abundance of Oaks and Pines, Magnoliaceæ (such as the Tulip-tree), a number of Leguminous trees, with thorny Smilax-shrubs and gigantic Reeds; the Gleditschiæ on the banks of the Ohio are evergreen, with climbing Bignoniæ; evergreen trees here correspond to those of Southern Europe, intermingled in the forests with Oaks, Beeches, Ash, and *Platanus occidentalis*.

In the southern hemisphere this zone includes part of New Zealand and Australia, where, again, evergreen trees are intermixed with forest-trees with deciduous leaves; shrubby Ferns abound, and the Leguminosæ and Myrtaceæ are well represented.

In South America, the Pampas-plains of Buenos Ayres fall in this zone, especially characterized by arborescent Grasses. Southern Chili represents the warm temperate vegetation with its evergreen forests of Myrtaceæ, Beeches, and Araucarias; the Fuchsia is also characteristic of this region. The Chilian Palm, like the dwarf Palm of Southern Europe and the Palmetto of North America, forms an outlier from the subtropical region.

5. *The Cooler Temperate Zones.*—Equatorial boundaries, the annual isotherms of 54°·5 F. (12° C.); polar boundaries, the isotherms of 41° F. (5° C.). The especial characteristics of these zones are the forests of deciduous trees with inconspicuous blossoms, intermingled with social Conifers, together with the Grass-pastures. Here the trunks of the trees are overgrown only with Mosses and Lichens; the Honeysuckle, the Ivy, and the Hop are the only important climbers, very different from the *Lianes* of the tropics. Shrubs are pretty frequent, but they mostly lose their leaves in winter, such as Roses, Brambles, *Viburna*, &c. The social Dwarf-grasses on good soil, with the Sedges, Cotton-grasses, and Mosses of wet ground, characterize the plains, and extensive Heaths prevail in some districts. The contrast between summer and winter is strongly marked in the aspect of vegetable life: the trees are stripped of their leaves, the herbs die down to dwarf tufts, or hide themselves altogether in the ground, and the snow covers the surface of the plains in severe weather; but the warmth of summer, which brings out a lively and varied show of flowers, is sufficiently high to ripen the seeds of many, and thus annuals are more numerous than they are further north.

This zone is not represented in Africa or in the South Sea. In South America it includes Patagonia.

6. *The Subarctic Zone.*—Equatorial boundary, the annual isothermal line of 41° F. (5° C.); polar boundary, the isotherm of 36°·5 F. (2° C.)

for the month of September. The southern boundary of this zone in the northern hemisphere corresponds pretty nearly to the limit of distribution of the Oak in Europe and the east coast of North America, the northern boundary to the limit of the distribution of trees.

The striking characteristic of this zone is, indeed, the predominance of the Coniferous trees in the woods, giving place northwards to the Birch and Alder, and generally alternating with Willows where the soil is moist. Green pastures occur universally, especially adorned with showy flowering herbs in the spring and summer.

7. *The Arctic Zone.*—The equatorial boundary is the isotherm of 36°·5 F. (2° C.) for the month of September, or the polar limit of arborescent vegetation in the northern hemisphere; the polar boundary is the isotherm of 41° F. (5° C.) for the month of July. The vegetation of this zone corresponds to what we understand commonly as Alpine shrubs, consisting chiefly of prostrate shrubs, with a peculiar tortuous and compact habit of growth, such as the alpine Rhododendra, Andromedæ, the dwarf Birch and Alder, the Bog-Myrtle and dwarf Willow, with a variety of low-growing perennial herbs, remarkable for the comparatively large size and bright colour of their flowers. Sedges and Cotton-grasses occur socially, in some places covering extensive tracts; but the grassy pastures of the last zones are replaced to a great extent by tracts covered with Lichens.

8. *The Polar Zone.*—Equatorial boundary, the isotherm of 41° F. (5° C.) for the month of July; polar limit, the isotherm of 36°·5 F. (2° C.) for the same month. This zone is characterized by presenting, in the four to six weeks of summer, an alpine vegetation devoid of even shrubs, and consisting of herbaceous perennials of dwarf habit, such as Saxifrages, Ranunculi, Pyrolæ, Potentillæ, Dryas, Draba, &c., and possessing, moreover, certain genera (such as *Parrya*, *Phippsia*, and others) which, although they extend into the Arctic zone, are not met with in the alpine regions of the mountains of the more southern regions. In Spitzbergen, the number of Cryptogamic plants is remarkable, the Lichens alone equalling the Flowering plants, and predominating even in mass as well as number of species.

Sect. 2. Regions of Altitude.

It is well known that the lofty mountains lying within the tropics exhibit a graduated variation of character in their vegetation, and that those which rise above the limit of eternal snow display more or less distinctly marked regions, representing the zones lying between the plains at the foot of such mountains and the eternal ice of the polar zone.

Humboldt divided the surface of tropical mountains into three zones, representing the tropical, temperate, and frigid zones of the globe, and indicated the principal subdivisions of these regions. Meyen attempted to lay down a more systematic representation of the conditions in question, corresponding to his division of the

earth's surface into zones. Great difficulty interposes here in any attempt at generalization, since local conditions, arising from aspect, and conformation of surface, either giving more or less of precipitous character, accompanied by sudden changes, or producing elevated plains, &c., cause such great differences, even within the limits of single mountain-systems, that no absolute rule can be applied. The rules laid down by Meyen apply pretty well to his zones within the limits of Europe; but, in the delineation of the regions of altitude of greater extent, great variation presents itself near the equator.

The Snow-line.—According to Meyen's views, the snow-line, beginning at the polar zone, rises between 1900 and 2000 feet above the level of the sea, and in the equatorial zone to 15,500 or 16,600 feet; and he divides the regions of altitude in accordance with this, raising each region between 1900 and 2000 feet in each zone, as he approaches the equator. Now at North Cape, which lies near the polar limit of our subarctic zone, and in Iceland, which is crossed by the same limit, the line of perpetual snow is at about 2000 feet; we may therefore take this as the snow-line of the *arctic zone*. The equatorial limit of the subarctic zone falls in Southern Norway, where the snow-line is at about 4000 feet; while the equatorial limit of our cold temperate zone is not far removed from the Alps and Pyrenees, where the snow-line rises to 8000 feet and more. In the south of Spain, lying within the warm temperate region, snow lies in isolated patches below 11,000 feet. In the district of Sierra Nevada, which is one of the best-known of the mountains of this zone, as regards vegetation, there is a subtropical region up to 600 feet, the true warm temperate vegetation extends up to about 4000 feet, a cold temperate vegetation from about 4000 to 6500; the vegetation then passes into a condition allied to the subarctic, but without trees, and characterized by shrubs of a similar nature to those of the arctic zone. This region extends to 8000 feet; and thence to the summits of 11,000 feet there is an alpine summer vegetation (snow lying for eight months out of the twelve), which, again, is intermediate in character between those of the arctic and polar, consisting chiefly of perennial herbs like the latter, but presenting a formation of turfy pasture to some extent in the warm season. In the Caucasus the snow-line is much higher.

In the subtropical zone, on the Peak of Teneriffe, we find the vegetation of the warm temperate zone from about 2000 to 4000 feet, a representation of the cold temperature from 3000 to over 6000 feet; at about 8000 feet the climate is subarctic. This mountain does not reach the snow-line.

In Mexico, lying in our tropical zone, the lines are respectively shifted up in about the same ratio. We see throughout, then, a deviation from Meyen's ratio, in the tendency of the colder zones to widen out on the mountains of warmer zones; but this is partly owing to our dividing the zones according to temperature, and not according to latitude.

If we attempt to lay down the conditions of the mountains of Asia under a similar point of view, we find greater deviations. The mass of elevated land in Central Asia modifies all the climatal conditions very much. The snow-lines of the mountains of the cold-temperate and warm-

temperate zones rise to 14,000 feet; that of the Himalayas to 18,000 feet in the northern parts. Our data scarcely suffice for the illustration of these modified conditions, and therefore we have confined ourselves to a limited number of the best-explored mountain-regions of the Old and New Worlds.

We now give a brief sketch of the characteristics of the different regions of altitude, as classified by Meyen.

1. *Region of Palms and Bananas.*—Corresponding to the equatorial zone, and already characterized under that head, p. 669.

2. *Region of Tree-Ferns and Figs.*—Corresponding to the tropical zone, p. 670. The genus *Ficus* is most prevalent in the elevated forests of the equatorial zone of the East Indies, giving them a remarkable character of gloomy grandeur and impervious density.

3. *Region of Laurels and Myrtles.*—Corresponding to the subtropical zone, p. 670.

4. *Region of Evergreen Trees.*—Corresponding to the warm-temperate zone, p. 670.

5. *Region of Deciduous Trees.*—Corresponding to the cold temperate zone, p. 671; but this region seems to be absent from the mountains in many parts of the tropical and equatorial zones, since the tree-limit is carried down by peculiarities of climate, which, on the other hand, favour the advance of more southern forms into the upper regions. In Java and Sumatra, stunted trees of the class belonging here replace the dwarf Conifers of European mountains, and form the tree-limit far below the altitude at which forests of tall Conifers occur in the more northern Himalayas,—a condition explained in some degree by the local circumstances of the equatorial mountains, which are deficient in the supplies of moisture furnished by the vast masses of snow resting perpetually upon the Himalayas.

6. *Region of Conifers.*—Corresponding to the subarctic zone, p. 671. This zone, characterized by the growth of Pines and Firs, is well represented on most mountains, with the exception of the Peruvian Cordilleras, where the Escalloniεæ are said to be substituted for them. But the Conifers do not always form the uppermost belt of trees, even when they flourish in a well-defined region. Thus the region of the Conifers, in a general sense, which reaches to the tree-limit with Pines in the Alps, Pyrenees, and the Andes of Mexico, includes, in the Scandinavian mountains, in the Himalayas, and the Caucasus, a region of Birches, which rise out of it to form the last representatives of arboreal vegetation.

7. *Region of Alpine Shrubs or of Rhododendra.*—This region corresponds to the Arctic zone, p. 672. In the Himalayas, dwarf Willows, Junipers, and species of *Ribes* or Current seem to represent the vegetation of this region; while on the Andes of Quito the genus *Befaria* appears to correspond in its geographical development to the Rhododendra of the north.

8. *Region of Alpine Herbs.*—Corresponding to the polar zone, p. 672, usually presenting only patches of vegetation scattered over a broken surface of ground, covered during the greater part of the year with snow, and exhibiting accumulations in all seasons in sheltered spots. Lichens abound here; *Lecidea geographica* has been found in most diverse localities where bare rock rises above the ground, forming generally the last trace of vegetation. The plants of this region are remarkable in many respects, in

none more than the beauty and comparatively large size that usually characterize their flowers. They are mostly of perennial growth, since, although the severe cold prevailing throughout the greater part of the year is unfavourable to the maturation and preservation of seeds, the thick covering of snow protects established plants from the severe frost; and it is known that they are arrested in warmer regions where winter frosts prevail without great accumulations of snow, precisely because they are then incapable of bearing the cold, to which they are directly exposed.

The great discrepancies existing between mountains occurring in the same zone indicate that local circumstances must have most powerful influence in determining the altitudes attained by the various classes of vegetation. We are not in a position to give the real temperatures of regions of altitude with any accuracy in most cases, or these would probably greatly assist in ascertaining the direct causes of aberration; for differences of temperature certainly accompany the difference of elevation attained by particular forms of plants. Good examples of the influence of the form and local conditions of mountains are furnished by Teneriffe, Ararat, the Himalayas, and the Rocky Mountains of North America. The first is an isolated mountain, exposed to the equalizing influence of the ocean; the second an isolated mountain situated in the interior of a continent; the two chains are portions of enormous systems of mountains extending over large regions in the interior of continents. To work out this subject thoroughly, however, it is necessary to observe not only the conditions of different mountains, but those of the different declivities of the same mountain; since, when great elevations are attained, chains of mountains form the boundaries of local climates, and present different conditions on the two faces.

Sect. 3. Division of the Globe into Regions having Characteristic Vegetation.

The character of the vegetation of different regions is influenced not merely by climate, but by the more remote causes referred to in the last Chapter, which have led to the distribution of plants over more or less extensive areas, and their restriction within narrow limits in other cases; further, by the habit of plants, as by a social mode of growth, by size, &c.

Many attempts have been made to divide the earth's surface into Botanical Regions, according to their characteristic vegetation. None of these can be regarded as satisfactory; but perhaps the generalizations of Schouw and Grisebach are, on the whole, those which suggest most to the student. We therefore introduce here a brief account of the regions into which those authors divide the globe.

Phyto-geographic Regions.—The regions established by Schouw are founded on the following principles:—

1. At least one half of the known species of plants of the tract constituting a botanical region are peculiar to it.

2. A fourth part of the genera of the region are either peculiar to it, or have so decided a maximum that they are comparatively rare in other regions.

3. The individual Orders of plants are either peculiar to the region or have a decided maximum there.

Grisebach's regions in many respects correspond with those of Schouw; each of them is further divided into zones according to altitude above the sea-level up to the line of perpetual snow. The limits of each region are fixed by mountain barriers, the presence of seas, and other impediments physical and climatic, and therefore varying in particular instances.

1. *Region of Mosses and Saxifrages (Arctic-Alpine, or Wahlenberg's Region).*

Mean temperature.—Polar regions, 2°–41° Fahr. (−17° to −5° C.).
Mountains in the south, 21°–37° Fahr. (−6° C. to −3° C.).

This corresponds to Grisebach's Arctic region, and includes those regions which lie beyond the limits of forest vegetation. The period of vegetation only lasts a few weeks.

Character.—Characteristic and predominant genera—Ranunculus, Arabis, Draba, Arenaria, Dryas, Potentilla, Saxifraga, Rhododendron, Azalea, Gentiana, Pedicularis, Salix, Musci, Lichenes. Of the polar countries especially—Coptis, Eutrema, Parrya, Diapensia, Andromeda, Ledum. Of the mountain regions—Cherleria, Campanula, Phyteuma, Primula, Aretia, Soldanella. Dwarf perennial herbs with comparatively large flowers of bright colours. Annuals and trees absent.

Predominant shrubs and half-shrubs of the polar countries.—Betula nana, Salix herbacea and other species, Rubus Chamæmorus, Empetrum nigrum, Andromeda hypnoides, A. tetragona, Arbutus alpina, A. Uva ursi, Azalea procumbens, Rhododendron lapponicum, Menziesia cærulea.

Predominant shrubs and half-shrubs of the mountains.—Juniperus nana, Alnus viridis, Salix reticulata, S. herbacea, Rhododendron ferrugineum, R. hirsutum, R. caucasicum, Vaccinium Myrtillus, V. uliginosum, Azalea procumbens, Arbutus alpina, A. Uva ursi, Empetrum nigrum.

Plants which approach very closely to the snow-line.—Ranunculus glacialis, Saxifraga oppositifolia, Silene acaulis; in the polar countries especially, Agrostis algida, Ranunculus hyperboreus, R. nivalis, Saxifraga rivularis, S. cernua, S. nivalis, Papaver nudicaule, Draba alpina, Lychnis apetala, Diapensia lapponica. In the mountain-regions, Saxifraga muscoides, S. bryoides, Cherleria sedoides, Aretia helvetica, A. alpina, Draba nivalis, Petrocallis pyrenaica, Arabis bellidifolia, Myosotis nana, Gentiana nivalis, Achillea nana, Linaria alpina. No cultivation in this region.

The flora, as a whole, as tabulated by Hooker, is decidedly Scandinavian. Some of its members are universally diffused throughout the globe, even in the tropics (on mountains); hence the Scandinavian flora is considered

to be the oldest existing flora. The most northern position in which flowering plants have yet been found is in Smith's Sound, in lat. 82° N., where Dr. Bessels found *Draba alpina*, *Cerastium alpinum*, *Taraxacum dens leonis*, and *Poa flexuosa*. (The principal authority on the subject of the Arctic Flora in its geographical aspect is Hooker, whose paper "On the Distribution of Arctic Plants" is included in the Linnæan Transactions, vol. xxiii.)

2. *Region of Umbelliferæ (North-European and North-Asiatic, or Linnæus's Region).*

Mean temperature, 29°–46° Fahr. (−2° to −8° C.).

This corresponds to Grisebach's Europæo-Siberian Forest region, and is characterized by uniform temperature and absence of a dry season. The Atlantic coast is milder than the inland continental regions. Grisebach establishes 7 zones of altitude:—1. The zone of the Sweet Chestnut, *Castanea vesca*; 2. The zone of *Pinus picea* (Germany); 3. The zone of the Turkey Oak, *Quercus Cerris* (Hungary); 4. The central Russian forest zone (Oaks); 5. The northern zone of Conifers (Larches, Pines, Firs, with Birch); 6. The zone of *Quercus mongolica*; and 7. The zone of *Betula Ermanni*.

General Character.—Umbelliferæ, Cruciferæ, Coniferæ, Amentaceæ, Graminaceæ, Carices, Fungi, Cichoraceæ, Cynareæ; in Asia, more particularly, saline plants (such as Salsola and Salicornia) and Astragaleæ. Luxuriant pastures; forest trees with deciduous leaves; a few Heaths.

Predominant trees and shrubs.—Pinus sylvestris, P. cembra, P. sibirica, Abies excelsa, A. pectinata, Larix europæa, Juniperus communis, Betula alba, Alnus glutinosa, A. incana, Fagus sylvatica, Quercus pedunculata, Q. sessiliflora, Carpinus Betulus, Castanea vesca, Salices, Populus tremula, Corylus Avellana, Ulmus campestris, Calluna vulgaris, Prunus spinosa, Pyrus Aucuparia, Acer Pseudo-platanus, A. platanoides, A. campestre, Tilia platyphylla, T. microphylla.

Cultivated plants.—Cereals: Rye, Barley, Oats, Wheat, Spelt, Maize, Millet (Panicum miliaceum), Buckwheat, Potato. Barley extends furthest to the north, followed southward by Rye, Oats, and Wheat.

Fruits.—Apple, Pear, Quince, Cherries, Plums, Apricot, Peach, Mulberry, Walnut, Grape, Currant, Gooseberry, Strawberry, Melons.

Esculent vegetables.—Cabbage, Rape, Turnip, Radish, Mustard, Peas, Beans, Lentils, Spinach, Beet, Cucumber, Gourd, Carrot.

Fodder plants, &c.—Clovers, Vetches, Lucerne, Rye-grass; Hops, Flax, Hemp, Tobacco. (The publications of Ledebour, Regel, and numerous other Russian botanists should be consulted as to this region.)

2a. *The Steppe Region.*

This region, as laid down by Grisebach, extends from the Black Sea to the frontiers of China, and from Southern Siberia to the Himalayas, thus including almost the whole of Central Asia. The climatal conditions are a severe winter, a short spring, a burning summer succeeded by winter,

The plants, then, native to it must be capable of growing in the short spring and, while at rest, be able to endure prolonged drought and intense extremes of temperature. Bulbous plants, plants with stiff spiny branches and small foliage, or plants densely covered with hairs, abound. Salt plains are abundant yielding a peculiar vegetation, including many Chenopods, such as the Saxal *Anabasis ammodendron*. (Humboldt's 'Asie Centrale' should be consulted on this region.)

3. *Region of the Labiatæ and Caryophylleæ (Mediterranean, or De Candolle's Region).*

Mean temperature, 65°–73° Fahr. (18°–23° C.).

This, the Mediterranean region of Grisebach, is characterized climatically by very hot dry summers and mild winters. Plants grow in spring, rest in the hot dry season, and grow again in autumn. Schouw includes the Atlantic islands in this botanical region.

Character.—Labiatæ, Caryophylleæ, Boragineæ, Cistineæ, Liliaceæ; the Orders cited in the preceding region, but mostly less prevalent, especially the Carices. Representatives of tropical Orders—Palmæ, Terebinthaceæ, Lauraceæ,—Orders which increase towards the equator becoming more numerous: Leguminosæ, Malvaceæ, Solanaceæ, Euphorbiaceæ, Urticaceæ.

Genera.—Adonis, Trigonella, Trifolium, Medicago, Genista, Cytisus, Scabiosa, Anthemis, Achillea, Verbascum, Narcissus; many evergreen trees and shrubs; a greater number of woody plants than in the second region; pasture less luxuriant; a winter flora existing.

Predominant trees and shrubs.—Evergreen trees and shrubs form a feature of the flora. Pinus Pinea, P. Pinaster, P. halepensis, P. Laricio, Cupressus sempervirens, Juniperus phœnicea, J. macrocarpa, Quercus Cerris, Q. pedunculata, Q. sessiliflora, Q. Ilex, Q. Suber, Q. Ægilops, Q. coccifera, Q. infectoria, Castanea vesca, Platanus orientalis, Alnus cordifolia, Corylus Colurna, Ostrya vulgaris, Acer monspessulanum, A. neapolitanum, Pistacia Lentiscus, P. Terebinthus, Ceratonia siliqua, Cercis siliquastrum, Genista scoparia, Mespilus pyracantha, Prunus laurocerasus, Tamarix gallica, T. africana, Myrtus communis, Punica Granatum, Opuntia vulgaris, Viburnum Tinus, Arbutus Unedo, Erica arborea, E. scoparia, Rhododendron ponticum, R. maximum, Cisti, Phyllyrea latifolia, P. angustifolia, Ornus europæa, O. rotundifolia, Nerium Oleander, Rosmarinus officinalis, Ephedra distachya, Chamærops humilis, Ruscus aculeatus, Smilax aspera, Tamus communis. (The highest parts of the mountains here belong to the first region, the middle elevations to the second region.) Many plants have been introduced and become quasi naturalized; such as the Date-Palm, *Agave americana*, *Opuntia*, *Eucalyptus globulus*, &c.

Cultivated plants.—The same as in the preceding region; but the following are more rare, or only seen on the mountains—Rye, Currants, Gooseberry, Buckwheat, and Hop; while the following are added:—

Cereals.—Rice, Millets (Sorghum vulgare, Panicum italicum).

Fruits.—Figs, Almond, Pistachia-nut, Lemon, Citron, Sweet and Seville Oranges, Prickly Fig (Opuntia), Water-Melon, Olive, the latter being characteristic.

Esculents &c.—Melongena, Tomato, Anise, Coriander, Cotton, White Mulberry, Saffron, Sumach, Lupins, Sainfoin.

Characteristic forms.—Sempervivum arboreum, S. canariense, S. tortuosum, &c., Ilex Perado, Cacalia, Kleinia, Sonchus fruticosus, Arbutus callicarpa, Ardisia excelsa, Ceropegia aphylla, Echium giganteum, &c., Laurus fœtens, Euphorbia balsamifera, E. canariensis, Myrica Faya, Pinus canariensis.

4. *Region of Asteres and Solidagines (Northern North-American, or Michaux's Region).*

Mean temperature, 9°–59° Fahr. (12°–15° C.).

The northern part of this region corresponds to the Europæo-Siberian region of Grisebach (p. 677), the Californian coast represents the Mediterranean region, while the central prairies are the analogues of the Asiatic steppes. The American forest region has a lower temperature than that of Europe. New York has about the summer temperature of Rome and the winter temperature of Copenhagen. The United States Flora, according to Gray and Hooker, consists of three main elements, an endemic American, a European, and an Asiatic; while that of the temperate Old World is, in a continental point of view, binary—Europe and Asia having many types in common, but very few representatives of the strictly American flora. The distribution of North-American plants, unlike the European, is mainly in a meridional direction, the difference of the floras of the Eastern, Central, and Western States being wonderfully great. The European components extend over the whole breadth of the continent, diminishing, however, to the westward. The American components present many localized genera, inhabiting the Eastern, Central, and Western States respectively; they increase in numbers and peculiarity, as also in restriction of range, towards the west. The Asiatic components are found both in the Eastern and Western States, but hardly at all in the Central; and some of them are common to both the east and west, while others are peculiar to each. But whereas the European components prevail on the side towards Europe, the maximum of Asiatic representation is on that remote from Asia. This has been conspicuously shown by Gray's discovery, in the Eastern States, of single representatives of Japanese genera previously supposed to be monotypic; and what is most noteworthy is, that such representatives are in some cases extremely rare local plants, found in single and very restricted areas, indicating a dying-out of the Asiatic representation in America.

Character.—More species of Coniferæ and Amentaceæ than in the second region, but fewer Umbelliferæ, Cruciferæ, Cichoraceæ, and Cynareæ.

Genera.—Hydrastis, Sanguinaria, Hudsonia, Ptelea, Robinia, Gymnocladus, Purshia, Gillenia, Decodon, Œnothera, Clarkia, Ludwigia, Bartonia, Claytonia, Heuchera, Itea, Hamamelis, Mitchella, Aster, Solidago, Liatris, Rudbeckia, Gaillardia, Vaccinium, Andromeda, Kalmia, Sabbatia, Houstonia, Hydrophyllum, Phlox, Monarda, Dodecatheon, Dirca, Hamiltonia, Lewisia, Trillium, Medeola.

Predominant trees and shrubs.—Pinus Strobus, P. inops, P. resinosa, P.

Banksiana, P. variabilis, P. rigida, P. serotina, P. pungens, Abies balsamea, A. taxifolia, A. canadensis, A. nigra, A. rubra, A. alba, Larix pendula, L. macrocarpa, Thuja occidentalis, T. sphæroidea, Juniperus virginiana, J. Sabina, Taxus canadensis, Quercus, 25 sp., Fagus sylvatica, F. ferruginea, Castanea americana, C. pumila, Ostrya virginica, Carpinus americana, Corylus americana, C. rostrata, Alnus glutinosa, A. crispa, A. serratula, Betula nigra, B. papyracea, &c., Salix, 27 sp., Populus balsamifera, P. monilifera, &c., Myrica cerifera, &c., Platanus occidentalis, Liquidambar styraciflua, Juglans nigra, J. cinerea, &c., Ulmus americana, &c., Nyssa aquatica, Fraxinus alba, F. nigra, &c., Ornus americana, Ribes floridum, R. aureum, &c., Vaccinium, 20 sp., Andromeda, 10 sp., Kalmia latifolia, K. angustifolia, K. glauca, Azalea viscosa, A. nitida, A. glauca, A. nudiflora, &c., Rhododendron maximum, Cornus florida, C. alba, C. canadensis, &c., Hamamelis virginiensis, Spiræa salicifolia, S. chamædrifolia, S. opulifolia, S. hypericifolia, &c., Gillenia trifoliata, Cratægus, sp., Cerasus pumila, C. nigra, &c., Purshia tridentata, Rubus, 20 sp., Pyrus sp., Robinia Pseud-acacia, R. hispida, Gymnocladus canadensis, Rhus typhina, R. glabra, R. venenata, R. toxicodendron, &c., Ptelea trifoliata, Ceanothus americanus, &c., Rhamnus alnifolius, &c., Ilex opaca, &c., Euonymus americanus, E. atropurpureus, Staphylea trifolia, Ampelopsis hederacea, Acer rubrum, A. dasycarpum, A. saccharinum, A. striatum, Negundo fraxinifolium, Xanthoxylum fraxineum, X. tricarpum, Tilia glabra, T. pubescens, Liriodendron tulipifera.

In the northern parts (to 50°–55° N. L.) no cultivation. South of this the same plants as those cultivated in the second region, but Maize more extensively. The Californian climate is very uniform, the resting period of vegetation occurring in the dry summer. Vines, Olives, Maize, Oranges, and fruit-trees of all kinds flourish here as well as Wheat, whilst the loftiest forest trees, the Sequoias, grow here as once they did in Britain.

The *Prairie Region* corresponds to the Steppe Region of Central Asia. Extremes of temperature and great drought are the characteristics of this region; salt plains exercise a marked influence on the vegetation, but where irrigation is practicable the country becomes very fertile.

The evidences of climatic changes in past eras of the existing flora of the continent, says Hooker, are seen in the prevalence of arctic and northern species of plants in the alpine zones of the meridional mountain-chains, the Appalachian, Rocky Mountains, and Sierra Nevada, even as far south as the 33rd parallel. These plants had spread southwards during a period of cold, and on its subsequent mitigation had retired to the lofty situations they now inhabit. To the former existence of a warmer climate we may partly look for the extension of Mexican types to the dry regions west of the Rocky Mountains up to the 41st parallel; and to it may be attributed the remarkable northward extension of the Cacti in a very narrow meridional belt, scarcely 100 miles broad, along the eastern flanks of the same mountains, from their headquarters in New Mexico, in the 33rd, almost to the 50th parallel.

(See Gray's 'Botany of the Northern United States,' and numerous publications of the American botanists on the Flora of their continent. Sir W. Hooker's 'Flora Boreali-Americana' should also be consulted.)

5. *Region of Magnoliæ (Southern North-American, or Pursh's Region).*

Mean temperature, 59°–73° Fahr. (15°–23° C.).

This region is included with the preceding in Grisebach's North-American Forest zone, but the vegetation is of a more tropical type, and evergreen exogenous trees are more abundant.

Character.—A certain approximation to the tropical vegetation; Canneæ (Canna, Thalia), Palmæ (Chamærops), Yucca, Cycadeæ (Zamia), Laurus, Ipomæa, Bignonia, Asclepias, Cacteæ (Mammillaria, Opuntia), Rhexia, Passiflora, Cassia, Sapindus.

Few Labiatæ, Caryophylleæ, Umbelliferæ, Cichoraceæ, Geranieæ; few species of Aster or Solidago.

Trees with broad shining leaves and large flowers.

Genera.—Magnolia, Liriodendron, Illicium, Asimina, Dionæa, Pavia, Amorpha, Gleditschia, Baptisia, Petalostemon, Calycanthus, Œnothera, Claytonia, Rudbeckia, Liatris, Silphium, Kalmia, Houstonia, Frasera, Halesia, Dodecatheon.

Predominant trees and shrubs.—Magnolia grandiflora, M. glauca, &c., Illicium floridanum, I. parviflorum, Liriodendron Tulipifera, Asimina, sp., Pavia flava, P. macrostachya, &c., Amorpha fruticosa, &c., Gleditschia triacanthos, &c., Robinia viscosa, Cassia Tora, C. marilandica, &c., Acacia glandulosa, Calycanthus floridus, &c., Kalmia hirsuta, K. cuneata, Opuntia vulgaris, O. fragilis, O. missouriensis, Halesia tetraptera, H. diptera, Laurus Catesbyanus, L. caroliniensis, L. Benzoin, L. Sassafras, &c., Juglans fraxinifolia, Carya aquatica, C. myristiciformis, Liquidambar styraciflua, Carpinus americanus, Castanea americana, C. pumila, Platanus occidentalis, Quercus, 25 sp., Taxodium distichum, Pinus Tæda, P. palustris, in the south *Pinus australis* covers large districts of sandy waste, Zamia integrifolia, Yucca gloriosa, Y. aloifolia, &c., Chamærops Hystrix, C. Palmetto, C. serrulata.

Cultivated plants.—About the same as in the third region, with the exception of the Olive. Cultivation of Rice more extensive. In the southern parts some tropical plants, especially Cotton and the Sugar-cane.

6. *Region of Camellieæ and Celastrineæ (Chinese, Japanese, or Kæmpfer's Region).*

Mean temperature, 54°–68° Fahr. (12°–20° C.).

This is the Chino-Japanese region of Grisebach. The climate is moderate with abundant, equally diffused rainfall. The country has been so long under cultivation, the forests destroyed, and much of the land altered by irrigation, that the natural characteristics are greatly obliterated.

Genera.—Magnolia, Nandina, Eurya, Camellia, Thea, Celastrus, Ilex, Euonymus, Bumalda, Hovenia, Kerria, Spiræa, Gonocarpus, Lagerstrœmia, Aucuba, Bladhia, Eleagnus, Polygonum, Pollia.

Predominant trees and shrubs.—Rhapis flabelliformis, Pinus sinensis, &c., Cunninghamia lanceolata, &c., Taxus nucifera, T. verticillata, Salisburia adiantifolia, Cryptomeria japonica, Cupressus pendula, Juniperus

virginiana, Thuja orientalis, T. dolabrata, Quercus glabra, Q. glauca, Alnus japonica, Juglans nigra, Broussonetia papyrifera, Daphne odora, Laurus glauca, L. lucida, L. umbellata, L. pedunculata, Olea fragrans, Diospyros Kaki, Mespilus japonica, Sophora japonica, Acer japonicum, A. septemlobatum, A. palmatum, &c., Camellia japonica, C. Sasanqua.

Cultivated plants.—Rice, Wheat, Barley, Oats, Doura (Sorghum vulgare), Millet (Eleusine corocana), Buckwheat, Sago (Cycas revoluta), Taro (Arum or Caladium esculentum), Batatas or Sweet Potato; various species of Pear, Apple, Crab, &c., Quince, Plum, Apricot, Peach, Medlar; many species of Citrus (Oranges, Shaddocks, &c.), Melons.

Tea, Rape (Brassica sinensis), Radish, Cucumber, Gourds, Water-Melon, Anise, Star-Anise, Soja, Nelumbium, Trapa, Scirpus tuberosus, Convolvulus reptans, Beans, Peas, Solanum æthiopicum, Sesamum, Hemp, Paper Mulberry, Cotton, Indigo, Isatis indigotica, Urtica nivea. (The publications of Bunge, Maximowicz, Bentham (Hong Kong), Siebold, Miquel, Gray, Franchet, and Savatier are amongst the principal dealing with this region.)

7. *Region of the Scitamineæ* (*Indian, or Roxburgh's Region*).

Mean temperature, 66°–83° Fahr. (19°–29° C.).

This corresponds nearly to Grisebach's Indian Monsoon region, and is tropical in character, varying according to altitude and the direction of winds, the degree of moisture, &c. The growing period for plants is in the rainy season. It includes the Indo-Malayan region with the islands of Java, Borneo, New Guinea, &c.

Character.—The tropical Orders make their appearance, or become more abundant: Palmaceæ, Cycadaceæ, Scitamineæ, Aroideæ, Artocarpaceæ, Urticaceæ, Euphorbiaceæ, Lauraceæ, Convolvulaceæ, Bignoniaceæ, Apocynaceæ, Rubiaceæ, Leguminosæ, Terebinthaceæ, Meliaceæ, Guttiferæ, Sapindaceæ, Byttneriaceæ, Malvaceæ.

The extra-tropical vanish, or only present themselves sparingly: Cariceæ, Coniferæ, Amentaceæ, Labiatæ, Boragineæ, Compositæ, Rosaceæ, Caryophylleæ, Cistaceæ, Cruciferæ, Ranunculaceæ.

Genera.—Uvaria, Grewia, Eriolæna, Garcinia, Buchanania, Crotalaria, Flemingia, Butea, Carpopogon, Jambosa, Gratiola, Tectona, Holmskioldia, Ficus, Phytocrene, Calamus.

The trees are never without leaves. The number of arborescent plants is greater than outside the tropics. Large and splendid flowers. Many climbing, parasitical, and epiphytic plants.

Predominant arborescent plants.—Dillenia ornata, D. scabrella, Uvaria, sp., Michelia Champaca, &c., Bombax insignis, &c., Sterculia, sp., Astrapæa Wallichii, Elæocarpus, sp., Calophyllum, sp., Garcinia, sp., Sapindus, sp., Swietenia febrifuga, Cissus, sp., Aquilaria malaccensis, Semecarpus Anacardium, Melanorrhœa usitata, Mimosa, sp., Acacia, sp., Amherstia nobilis, Pterocarpus santalinus, Cassia fistula, Jambosa, sp., Gardenia, sp., Nauclea, sp., Uncaria Gambir, Diospyros Ebenum, &c., Urceola elastica, Bignonia, sp., Avicennia tomentosa, Tectona grandis, T. Hamiltoniana, Laurus Cassia, L. Cinnamomum, L. malabathrica, Tetranthera, sp., Myristica, sp., Hernandia sonora, Ficus religiosa, F. indica (the Banyan), F. elastica, F. benja-

mina, and many others; Cycas revoluta, Borassus flabelliformis, Cocos nucifera, Calamus Rotang, C. rudentum, C. Draco, &c., Areca Catechu, Dracæna Draco, Pandanus odoratissimus, Bambusa arundinacea.

Cultivated plants.—Rice, Millets, &c. (Panicum frumentaceum, Eleusine coracana, Sorghum, sp.), Sago (Cycas circinalis), Yams, Ground-nut (Arachis), Cocoa-nut, Tamarind, Mango, Mangosteen, Bananas, Plantain, Rose-Apples (Eugenia, Jambosa), Guava, Oranges, Shaddock, Water-Melon, Sugar, Coffee, Cloves, Peppers, Ginger, Cardamoms, Turmeric, Cotton, Indigo, &c., Soja, Beans, Pulses (Dolichos, sp.), Opium, Poppy, &c.

(The publications of Roxburgh, Royle, Blume, Wight, Hooker, Thomson, Miquel, Beccari, and others on the botany of this region are very numerous. Hooker's 'Flora of British India' will be the most complete enumeration.)

8. *Region of Rhododendron-trees* (*Emodic, or Wallich's Region*).

Altitude, 5000–12,000 feet. *Mean temperature*, 66° Fahr. (19° C.).

Character.—Included in Grisebach's Indian Monsoon region, of which it forms a marked subdivision. Tropical forms disappear or decrease:—Palmaceæ, Cycadaceæ, Scitamineæ, Euphorbiaceæ, Convolvulaceæ, Apocynaceæ, Terebinthaceæ, Leguminosæ, Malvaceæ, Anonaceæ.

Extratropical, especially European, forms come to light, or become more abundant than in 7, such as Cariceæ, Amentaceæ, Coniferæ, Polygoneæ (Rumex, Polygonum, Rheum), Primulaceæ (Primula, Lysimachia), Labiatæ, Ericaceæ (Rhododendron, Andromeda), Cichoraceæ, Umbelliferæ, Rosaceæ (Potentilla, Rubus, Rosa, Pyrus, Mespilus, Prunus), Aceraceæ, Caryophyllaceæ (Stellaria, Cerastium, Arenaria), Cruciferæ, Ranunculaceæ (Aconitum, Ranunculus, Thalictrum). The Orchideæ and Ferns are very numerous. Other characteristic forms are the

Genera.—Allium, Paris, Plantago, Veronica, Rhinanthus, Pedicularis, Didymocarpeæ, Gentiana, Swertia, Campanula, Valeriana, Galium, Cornus, Viburnum.

Most important trees and shrubs.—Pinus Pindrow, P. Webbiana, P. excelsa, P. Khutrow, P. Gerardiana, Abies Smithiana, A. Browniana, Cedrus Deodara, Cupressus torulosa, Podocarpus latifolia, Juniperus squamata, J. excelsa, Quercus spicata and ten other sp., Corylus ferox, Betula utilis, B. nitida, B. alnoides, Alnus nepalensis, Salix disperma, S. cuspidata, S. japonica, Daphne cannabina, D. Gardneri, D. sericea, Elæagnus arborea, E. conferta, E. umbellata, Hippophaë salicifolia, Fraxinus floribunda, Ligustrum nepalense, L. bracteolatum, Xylosteum ligustrinum, Caprifolium japonicum, C. macranthum, Cornus oblonga, C. capitata, Viburnum fœtidum, &c., Andromeda formosa, A. ovalifolia, &c., Rhododendron arboreum, R. barbatum, R. Falconeri, and many other sp.; Ilex dipyrena, I. odorata, &c., Ribes Takare, Rosa microphylla, &c., Rubus rugosus, R. betulinus, &c., Spiræa canescens, &c., Neillia thyrsiflora, M. rubiflora, Mespilus affinis, &c., Prunus undulata, P. cerasoides, Rhus juglandifolium, R. fraxinifolium, &c., Rhamnus, sp., Celastrus, sp., Euonymus, sp., Acer acuminatum, A. oblongum, Dobinæa vulgaris, Magnolia, sp., Berberis asiatica, B. Wallichiana.

[illegible]—The western portion of the Himalayas differs considerably from

the eastern portion, from the predominance of Dicotyledonous forests and a damp climate in the former, with a variety of Conifers until the limit of Abies Smithiana (10,000 feet) is attained, and an extension of the tropical plants to a greater altitude; while in the drier eastern portion the Conifers are diffused throughout, the forests less considerable, and the plants of temperate climates diffused lower down.

Cultivated plants.—The cereals and orchard fruits of Europe, mountain Rice, and a few tropical plants in the lower regions.

(For the Indian flora consult Roxburgh's 'Flora Indica,' Hooker and Thomson's 'Flora Indica' (a most valuable introductory treatise), Hooker's 'Flora of British India,' and numerous memoirs by Wallich, Wight, Griffith, and many other botanists, principally British. For the Sikkim Himalayan see especially Hooker's publications.)

9. *Polynesian* (*or Reinwardt's*) *Region.*

Mean temperature, 66°–84° Fahr. (19°–29° C.). *Altitude,* 0–5000 feet.

Character.—Resembling that of the Indian region, and included by Grisebach in his Indian Monsoon region. The principal distinction consists in the greater number of Orchideæ (especially parasitic species, which appear here in many peculiar forms), of Ferns, and species of Ficus. A slight approximation to the Australian forms: Melaleuca, Metrosideros, Proteaceæ (Heliophyllum). Among the other characteristic forms are the

Genera.—Licuala, Lodoicea, Rafflesia, Brugmansia, Stemonurus, Antiaris, Myristica, Nomaphila, Hydrophytum, Philagonia, Esenbeckia, Echinocarpus, Aromadendron.

Predominant trees and shrubs.—Primæval forests, composed especially of species of Ficus, Lauraceæ, Calameæ, and Bignoniaceæ, with Licuala speciosa, Broussonetia papyrifera, Artocarpus incisa, Antiaris toxicaria (Upas), Myristica, sp., Ardisia, sp., Tectona grandis, Strychnos tieute, Diospyros, sp., Barringtonia speciosa, B. excelsa, Philagonia procera, Cereus, sp., Calophyllum Inophyllum, Elæocarpus, sp., Esenbeckia altissima, Echinocarpus Sigun.

Cultivated plants.—The same as in the Indian region, with Bread-fruit, Cassava, Inocarpus edulis, Nutmeg, Camphor, Papaw, Cotton (tree, &c.), Paper-mulberry, Hemp.

10. *Upper Javan* (*or Blume's*) *Region.*

Altitude, 5000–12,000 feet.

Character.—This region, like the preceding included in Grisebach's Indian Monsoon region, bears a certain resemblance to the Emodic region, and ought perhaps to be united with it. Extratropical forms replace the tropical. Oak-woods replace the forests of Ficus; and these are succeeded by forests of Podocarpus mingled with Ternstrœmiaceous trees, above which the shrubby Heaths (Thibaudia) and woody Gnaphalia occur at a comparatively low elevation (9000 feet), where the trees cease.

Genera.—Plantago, Lysimachia, Veronica, Gentiana, Swertia, Vaccinium, Gaultheria, Vireya, Thibaudia, Bellis, Galium, Saprosma.

Characteristic trees and shrubs.—Ternstrœmiaceæ (Cleyera), Gordonia, Schima, Eurya, Meliaceæ, arborescent Eupatorieæ, Lauraceæ, Ficus, Podocarpus amara, P. imbricata, P. latifolia, P. bracteata, Agathis loranthifolia, Quercus, 16 sp., Myrica javanica, Castanea javanica, C. argentea, &c., Dithocarpus javensis, Engelhardtia spicata, E. rigida, Thibaudia, sp., Viburnum, sp., Sambucus javanica, Hæmospermum arboreum, Mespilus, sp.

(For further information on the botany of this region the publications of Blume, Miquel, Beccari, and other botanists should be consulted.)

11. *Oceanic (or Chamisso's) Region.*

Mean temperature, 73°–83° Fahr. (23°–29° C.).

Character.—A sparing and not very peculiar flora. Greater approximation to the flora of Asia than to that of Africa; some affinity to the Australian (Casuarina, Proteaceæ, Myoporum, Epacrideæ, Melaleuca, Acaciæ aphyllæ).

Genera.—Schiedea, Antholoma, Aporetica, Crossostylis, Codia, Timonius, Kadua, Cyathostegia, Argophyllum, Melodinus, Ascarina.

Predominant trees and shrubs.—Dracæna terminalis, Tacca pinnatifida, Pandanus odoratissimus, Cocos nucifera, Corypha umbraculifera, Cupressus columnaris, Casuarina equisetifolia, C. nodiflora, Ficus, sp., Artocarpus incisa, Aleurites triloba, Embothrium strobilinum, Scævola Kœnigii, Vaccinium cereum, Lobelia arborea, &c.; Coffea kaduana, C. Mariniana, Kadua Cookiana, &c., Rhizophora Mangle, R. gymnorhiza, Terminalia Catalpa, Barringtonia speciosa, Melaleuca virgata, &c., Osteomeles anthyllidifolia, Cassia Sophora, Mimosa Mangium, Adenanthera scandens, Blackburnia pinnata, Calophyllum Inophyllum, Clusia sessilis, C. pedicellata, Sapindus Saponaria, Dodonæa spathulata, D. viscosa, Aporetica pinnata, A. ternata, Grewia Mallococca, Sterculia Balangas, S. fœtida, Commersonia echinata, Tetracera Euryandra.

Cultivated plants.—Bread-fruit, Taro (Arum esculentum), Arum sagittifolium, A. microrhizon, Tacca pinnatifida, Convolvulus chrysorhizus, Yam (Dioscorea alata), Cocoa-nut, Banana, Inocarpus edulis, Sterculia Balangas, Ficus aspera, F. Granatum, Shaddock, Hog-plum (Spondias dulcis), Mimusops dissecta, Terminalia glabra, Cratæva religiosa, Eugenia malaccensis, Dracæna terminalis, Macropiper methysticum, Areca oleracea, Paper-mulberry.

(Seemann's 'Flora Vitiensis' may be consulted for a complete list of the plants of Fiji, &c.)

12. *Region of Balsamic trees (Arabian or Forskål's Region).*

This and the following region are properly grouped in one region by Grisebach, the broad climatal and botanical features being the same from the Atlantic to the Indian Ocean, south of the Mediterranean district and north of the Central African region. It extends to Arabia, Scinde, and the Punjab. Great heat and almost rainless seasons are characteristic. The vegetation is peculiar, consisting often of spiny, bulbous, or succulent plants.

Character.—Tropical; in greatest part, Indian forms.

Characteristic genera.—Stræmia, Mærua, Serræa, Oncoba, Caucanthus, Geruma, Balsamodendron, Cadia, Orygia. Some approximation to the South-African flora (Stapelia, Hæmanthus).

Predominant trees and shrubs.—Pandanus odoratissimus, Ficus Sycamorus, F. salicifolia, F. populifolia, F. Forskålii, F. palmata, F. serrata, F. Sur, F. Toka, Avicennia tomentosa, Cynanchum arboreum, Balsamodendron gileadense, B. Opobalsamum, B. Kataf, B. Kaful, Celastrus edulis, C. parviflora, Grewia populifolia, Mærua uniflora, M. racemosa.

Cultivated plants.—Millets (species of Sorghum), six-rowed Barley, Maize, Arum Colocasia, Date-palm, Plantain, Cocoa-nut, Tamarind, Fig, Papaw, Peach, Apricot, Plum, Apple, Quince, Vine, Coffee, Sugar, Ginger, Radish, Spinach, Gourd, Dolichos, sp., Tree-cotton, Indigo.

Note.—This region extends to the plains of North-east India (Scinde), and should probably include part of Persia and also of the Abyssinian region. (Boissier's 'Flora Orientalis' is a most valuable book on the flora of these regions. See also Cosson's memoirs.)

13. *The Desert Region* (*Delile's Region*).

Mean temperature, 73°–86° Fahr. (23°–30° C.).

Character.—This region, like the preceding, is subject to the unchecked prevalence of trade-winds. It varies in character according to the rocky or sandy character of the plains, the presence of oases, &c. A very poor flora. No characteristic Orders or genera, but the following species: Pennisetum dichotomum, Phœnix dactylifera, Cucifera thebaica, Euphorbia mauritanica, Ærua tomentosa, Acacia nilotica, A. arabica, A. gummifera, A. Senegal, Cassia obovata, C. Singueana, Alhagi maurorum, Mimosa Habbus, Zizyphus Palma Christi, Zygophyllum simplex, Z. album, Fagonia arabica, F. Oudneyi.

Cultivation.—Only in the Oases; here principally the Date-Palm. Doura (Sorghum vulgare), Wheat, Barley. South-European and certain Indian fruits.

14. *Region of Tropical Africa* (*Adanson's Region*).

Mean temperature, 73°–86° Fahr. (23°–30° C.).

Character.—The Sudan region of Grisebach; is remarkable for the large number of peculiar generic types, each often containing but few species. Leguminosæ, Rubiaceæ, Cyperaceæ very prevalent. Comparatively few species of Palmaceæ, Filices, Scitamineæ, Piperaceæ, Passifloreæ.

Genera.—Adansonia, Dombeya, Melhania, Christiania, Pentadesma, Napoleona, Parkia, Thonningia.

Predominant trees and shrubs.—Anona senegalensis, &c., Cadaba farinosa, Cratæva Adansonii, Capparis edulis, Pentadesma butyracea, Bombax pentandrum, B. guineense, Adansonia digitata, Sterculia acuminata, Grewia carpinifolia, Acacia, sp., Cassia occidentalis, Pterocarpus esculentus, Parkia africana, Chrysobalanus Icaco, Conocarpus pubescens, Rhizophora, sp., Psychotria, sp., Bignonia tulipifera, Avicennia africana, Euphorbia (shrubby species), Ficus, sp., Elais guineensis, E. melanococca, Rhapis vinifera, Phœnix spinosa, Pandanus candelabrum.

Cultivated plants.—Maize, Rice, Millets (Sorghum vulgare, saccharatum, Panicum, sp.), Yam (Dioscorea alata, sativa), Cassava, Arum esculentum, Plantains, Mango, Papaw, Pine-apple, Oil-palm, Cashew-nut, Figs, Tamarind, Citrus, sp. (Oranges, Limes, Lemons, &c.), Coffee, Sugar, Ginger, Cardamoms, Grains of Paradise, &c., Beans of various kinds, and Dolichos pulses, Ground-nut (Arachis), edible Solana, Cotton, Tobacco. (For information respecting the flora of this district, see specially Oliver's 'Flora of Tropical Africa,' Peters's 'Mossambique,' Hooker's 'Niger Flora,' various papers of Burchell, Welwitsch, and others.)

Intermediate in position and in characteristics between the preceding region and the South-African or Cape Region is Grisebach's *Kalahari Region*, a dry stony desert, without oases. Spiny Acacias and bulbous plants manage to live, as well as Cucurbits, succulent Vines, and, most curious of all, the strange *Welwitschia.*

15. *Region of Cacti and Piperaceæ* (*Jacquin's Region*).

Mexico, Guiana, &c.

Altitude, up to 5000 feet. *Mean temperature*, 68°–84° Fahr. (20°–29° C.).

Character.—Bromeliaceæ, Piperaceæ, Passifloraceæ, Cactaceæ, Euphorbiaceæ, Convolvulaceæ, Apocynaceæ, Rubiaceæ. Tropical Orders less frequent here than in other places within the tropics: Filices, Scitamineæ, Orchidaceæ, Myrtaceæ, Leguminosæ, Terebinthaceæ, Aurantiaceæ, Tiliaceæ, Malvaceæ. Extratropical Orders appearing or becoming more abundant: Labiatæ, Ericaceæ, Campanulaceæ, Compositæ, Umbelliferæ, Crassulaceæ, Rosaceæ, Caryophyllaceæ, Cruciferæ, Ranunculaceæ.

Characteristic genera.—Phytelephas, Kunthia, Galactodendron, Podopterus, Salpianthus, Russellia, Lagascea, Gronovia, Inga, Thouinia, Lacepedia, Theobroma, Guazuma.

Predominant trees and shrubs.—Cyathea spinosa, C. villosa, Meniscium arborescens, Agave americana, Yucca acaulis, Cocos nucifera, C. butyracea, Mauritia flexuosa, Martinezia caryotifolia, Oreodoxa montana, Kunthia montana, Chamærops morini, Corypha Miraguama, C. Pumos, C. tectorum, &c., Liquidambar styraciflua, Cecropia peltata, Galactodendron utile, Rhopala ovata, Avicennia tomentosa, Ehretia ternifolia, Cordia dentata, Cereus, sp., Melocactus, sp., Opuntia, sp., Pereskia, sp., Mammillaria, sp., Lecythis elliptica, &c., Bertholletia excelsa, arborescent Melastomæ, Bauhinia splendens, B. suaveolens, &c., Hæmatoxylon campechianum, Cæsalpinia cassioides, &c., Acacia cornigera, A. fœtida, &c., Hymenæa Courbaril, &c., Inga Humboldtiana, I. insignis, &c., Mimosa, sp., Swietenia Mahogani, Bonplandia trifoliata.

Cultivated plants.—Maize, Doura, Cassava, Yam, Batatas, Plantain, Mango, Custard-apples, Guavas, Cocoa-nut, Papaw, Peach, Pine-apple, Cashew-nut, Tamarind, species of Citrus, Granadilla, Vine, Cactus-fig, Rose-apple, Cocoa, Vanilla, Coffee, Sugar, Tomatos, Capsicums, Pigeon-peas (Cajanus), Ground-nut, Cochineal-cactus, Tobacco, Cotton.

Grisebach very properly separates the cisæquatorial region of South America from the Mexican region. The shores of northern South America, as well as the river districts of the Orinoco and Amazon, are covered with dense forests, with few Conifers, but many Palms and climbing plants.

The savannahs and llanos are plains or plateaux covered with grass, with few trees, and sometimes deserts.

16. *Region of the Mexican Highlands* (*Bonpland's Region*).

Altitude, above 5000 feet. *Mean temperature*, 67°–79° Fahr. (20°–27° C.).

Character.—The climate of the Mexican Highlands is very uniform. Tropical forms vanishing or decreasing: Tree-ferns, Palmaceæ, Piperaceæ, Euphorbiaceæ, Melastomaceæ, Passifloraceæ. Extratropical forms make their appearance or become more abundant: Amentaceæ (Salix, Quercus), Coniferæ (Pinus, Cupressus), Labiatæ (Salvia, Stachys, Marrubium), Pedicularis, Anchusa, Myosotis, Polemonium, Ericaceæ (Vaccinium, Arbutus, Arctostaphylos), Compositæ (greatly increasing), Valeriana, Galium, Cornus, Caprifolium, Umbelliferæ, Rosaceæ (Amygdalus, Mespilus, Rosa, Potentilla), Caryophylleæ (Arenaria), Cruciferæ (Draba), Ranunculaceæ (Anemone, Ranunculus).

Characteristic genera.—Mirabilis, Maurandya, Leucophyllum, Holtzia, Dahlia, Zinnia, Schkuhria, Ximenesia, Lopezia, Vauquelinia, Choisya, Cheirostemon.

Predominant trees and shrubs.—Forests of Oaks and Conifers. Pinus occidentalis, Abies hirtella, Cupressus thurifera, C. sabinoides, Taxodium distichum, Quercus (16 sp.), Salix Bonplandiana, S. paradoxa, &c., Arbutus mollis, A. petiolaris, Arctostaphylos polifolia, A. pungens, &c., Vaccinium geminiflorum, V. stamineum, V. confertum, Rosa Montezumæ, Mespilus pubescens, Amygdalus microphylla, Cheirostemon platanoides.

Cultivated plants.—Maize, European cereals, Olives and fruits, and especially Agave americana.

Note.—In the uppermost regions of the mountains the flora acquires an alpine aspect. Here occur Cyperus toluccensis, Chelone gentianoides, Cnicus nivalis, Ageratum arbutifolium, Senecio (many procumbent species), Potentilla ranunculoides, Lupinus elegans, L. montana, Arenaria bryoides.

(For the geographical botany of this and adjacent districts the volume preparing by Mr. Hemsley for Messrs. Salvin and Godman's 'Natural History of Mexico and Central America' will be most important.)

17. *Region of Cinchonas* (*Andes, or Humboldt's Region*).

Altitude, 5000–9000 feet. *Mean temperature*, 59°–68° Fahr. (15°–20° C.).

Character.—The tropical Andean region of Grisebach. The Pacific slope is very sudden, the coast being nearly rainless and the vegetation poor. On the eastern slope of the Cordilleras a long summer rainy season is very favourable to forest vegetation, among which the Cinchona-yielding trees may be specially mentioned. Extratropical forms make their appearance, or become more frequent: Graminaceæ, Amentaceæ (Quercus, Salix), Labiatæ (Salvia, Stachys, Scutellaria), Anchusa, Myosotis, Swertia, Ericaceæ, Compositæ (very numerous), Caprifoliaceæ (Viburnum, Sambucus), Umbelliferæ (Ferula, Ligusticum), Rosaceæ, Cruciferæ, Ranunculaceæ. On the other hand, certain tropical forms vanish or become rarer, but a few particular species of Palmæ, Piperaceæ, Cactaceæ, Passifloreæ, and Melastomaceæ ascend to a considerable altitude.

Genera.—Lilæa, Cervantesia, Oreocallis, Lachnostoma, Gaylussaccia, Stevia, Flavéria, Tagetes, Espeletia, Cinchona, Guilleminia, Loasa, Kageneckia, Negretia, Amicia, Perottetia, Dulongea, Laplacea, Freziera, Abatia, Monnina.

Predominant trees and shrubs.—Oreodoxa frigida, Ceroxylon andicola, Podocarpus taxifolia, Salix Humboldtiana, Quercus Humboldtiana, Q. almaguerensis, Q. tolimensis, Ficus velutina, Rhopala cordifolia, Oreocallis grandiflora, Persea lævigata, P. Mutisii, P. sericea, Ocotea mollis, O. sericea, Vaccinium caracasanum, Andromeda bracamorensis, Befaria glauca, B. ledifolia, Cinchona Condaminea, C. cordifolia, C. oblongifolia, C. lancifolia, &c., Weinmannia elliptica, W. Balbisiana, &c., Osteomeles glabrata, Rubus floribundus, Ilex bumelioides, I. myricoides, Clusia elliptica.

Cultivated plants.—The tropical cultivated plants mentioned under 15 almost entirely disappear; Maize and Coffee, however, are cultivated in this region; after these come the European cereals and fruits, Potatoes, and Chenopodium Quinoa. (Humboldt's publications afford the best general view of the vegetation of this district.)

18. *Region of Escalloniæ and Calceolariæ* (*Ruiz and Pavon's Region*).

Altitude, 9000–18,000 feet. *Mean temperature*, 59°–34° Fahr. (15°–1° C.).

Character.—This is nearly the same as the Chilian transition region of Grisebach, intermediate between the Antarctic region to the south and the Andean region to the north; eastward are the Pampas. The general climate is like that of the Mediterranean, but with longer periods of drought. The tropical forms have disappeared almost entirely, but the following genera still occur:—Tillandsia, Oncidium, Peperomia, Rhexia, Passiflora. The forms which characterize the colder temperate and the polar zones become more common: Lichens, Musci, Carex, Luzula, Alnus, Rumex, Plantago, Gentiana, Swertia, Vaccinium, Campanula, Cacalia, Senecio, Umbelliferæ, Valeriana, Saxifraga, Ribes, Rubus, Alchemilla, Caryophyllaceæ (Sagina, Arenaria, Cerastium, Stellaria), Cruciferæ (Draba, Arabis).

Predominant Orders.—Compositæ, Graminaceæ, Ericaceæ. No large trees.

Characteristic genera.—Desyeuxia, Tigridia, Gardoquia, Calceolaria, Thibaudia, Lysipoma, Barnadesia, Homanthis, Chuquiruga, Culcitium, Wernera, Dumerillia, Escallonia, Pectophytum, Klaprothia, Polylepis.

Predominant shrubs.—Alnus ferruginea, A. acuminata, Vaccinium acuminatum, V. empetrifolium, V. floribundum, &c., Thibaudia rupestris, T. floribunda, T. longifolia, T. strobilifera, Befaria grandiflora, B. coarctata; Ribes frigidum, Escallonia myrtilloides, E. tortuosa, E. berberidifolia, Ilex scopularum, Drymis granatensis.

(Gay's 'Flora of Chili,' and Miers and Weddell's publications on the flora of Chili, Bolivia, &c., may be consulted for further details.)

19. *West-Indian* (*or Swartz's*).

Mean temperature, 59°–79° Fahr. (15°–26° C.).

Character.—Tropical heat with two rainy seasons are very favourable to the growth of plants, but the original character of the flora has

much altered by cultivation. The flora of this group of islands approaches that of the adjacent continent, but is distinguished especially (like the Polynesian from the Indian flora) by the great quantity of Filices and Orchidaceæ. In addition to these Orders, we find among the characteristic forms the following:—

Genera.—Thrinax, Epistylium, Alchornea, Tanaëcium, Tetranthus, Catesbæa, Belonia, Portlandia, Picramnia, Legnotis, Lithophila, Valentinia, Hypelate.

The following are deserving of mention among the predominant trees and shrubs:—Cocos nucifera, Pinus occidentalis, Laurus, sp., Melastoma, sp., Myrtus, sp., Sterculia, sp., Uvaria, sp.

Cultivated plants the same as in 15.

(Grisebach's 'Flora of the West Indies' is the best general guide to the flora of these islands.)

20. *Region of Palms and Melastomæ* (*Brazilian of Martius's Region*).

Mean temperature, 59°–84° Fahr. (15°–29° C.).

Character.—The Amazon district is perhaps best placed with the cis-æquatorial. The central Brazilian region consists of a mountain range to the east, near the coast, and in the interior high tableland. In the dry season vegetation is dormant, but extraordinarily varied and vigorous in the rainy season. Probably it is that portion of the globe in which the Vegetable Kingdom presents the greatest profusion and variety. Abundance of genera and species, magnitude of individuals, impenetrable (primæval) forests, numerous climbing and parasitical plants. Among the characteristic, although not peculiar Orders may be named Palmaceæ, Hæmodoraceæ, Gesneraceæ, Melastomaceæ, and Sapindaceæ; the Vochysiaceæ are peculiar. The peculiar genera are too numerous to be mentioned here; among those richest in species are the

Genera.—Vellosia, Barbacenia, Manihot, Franciscea, Ditassa, Lycnophora, Diplusodon, Kielmeyra, Sauvagesia, Lavradia.

Characteristic genera and species, according to the different modes of occurrence.—In the primæval forests: Palms of various genera, Ficus, Cecropia, Anda, Rhopala, Myristica, Bignonia, Theophrasta, Stifftia, Oxyanthus, Coutarea, Psychotria, Bertiera, Feuillea, Carica, Myrtus, Gustavia, Lecythis, Bertholletia, Melastoma, Hymenæa, Dimorpha, Trattinickia, Pilocarpus, Trichilia, Cedrela, Cupania, Banisteria, Hippocratea, Caryocar, Marcgravia, Clusia, Calophyllum, Sloanea, Göthea, Lebretonia, Abroma, Carolinea, Bixa, Uvaria.

In the Catingas (or open woods, where the trees lose their leaves in the dry season): Jatropha, sp., Acacia, sp., Mimosa, sp., Cæsalpinia pubescens, &c., Spondias tuberosa, Thryallis brasiliensis, Chorisia ventricosa, Bombax, sp., Eriodendron, sp., Pourretia ventricosa, Capparis lineata, &c., Anona obtusifolia, &c.

In the Campos (open treeless plains): Paniceæ, Amaryllis, Alstrœmeria, Vellosia, Barbacenia, Burmannia, Stelis, Cnemidostachys, Rhopala, Laurus, Ocotea, Gomphrena, Lantana, Echites, Hancornia speciosa, Gesnera, Lycnophora, Baccharis, Vernonia, Mikania, Stevia, Melastoma, Rhexia, Terminalia fagifolia, Gaudichaudia, Sauvagesia, Lavradia, Plectanthera.

On the sea-coasts: Cocos schizophylla, Diplothemium maritimum, Eriocaulon, sp., Xyris, sp., Avicennia tomentosa, Rhizophora Mangle, Conocarpus erectus, racemosa, Bucida Buceras.

Cultivated plants, about as in 15.

(The most detailed works on the flora of this region are the splendid works of Von Martius, continued by Eichler and other botanists.)

21. *Region of shrubby Compositæ* (*Extratropical S.-American, or St.-Hilaire's Region*).

Mean temperature, 59°–74° Fahr. (15°–23° C.).

Character.—The tropical forms decrease or vanish; extratropical, especially European, forms take their place. Ranunculaceæ, Cruciferæ, Helianthemum, Caryophyllaceæ, Lathyrus, Galium, Teucrium, Plantago, Carex; a few South-African forms, Polygala, Oxalis, Gnaphalium. This region has more than half its genera in common with Europe. Numerous Compositæ; many among these shrubby.

Genera.—Larrea, Hortia, Diposis, Boopis, Acicarpha, Cortesia, Petunia, Jaborosa, Tricycla, Caperonia, Bipennula. The vegetation of the Pampas here takes its character from the long periods of drought, no rainy seasons occurring, and only occasional thunder-storms. Arborescent vegetation is scanty or entirely absent. Spiny shrubs and salt plants are found in the interior. *Onopordon Acanthium* has in some districts overrun the whole country, displacing the few native plants.

Cultivated plants.—Mostly the European: Wheat, Vine. The Peach is very widely spread.

22. *The Antarctic Region* (*D'Urville's Region*).

Mean temperature, 41°–48° Fahr. (5°–9° C.).

Character.—Climate of northern portion mild, equable, damp. Great resemblance to the North-European flora (Region 2). The tropical forms have entirely vanished. Forests prevail in the south; *Fagus antarctica* and an evergreen species are abundant. In the extreme south Saxifrages, Ranunculi, &c. prevail.

Predominant Orders.—Compositæ, Graminaceæ, Cariceæ, Musci, Lichenes. The following are also common: Ranunculaceæ, Cruciferæ, Caryophyllaceæ, Rosaceæ, Umbelliferæ. Two thirds of the genera in common with Europe. A slight approximation to South Africa (Gladiolus, Witsena, Galaxia, Crassula) and to Australia (Embothrium, Ourisia, Stylidiæ, Mniarum).

Characteristic genera.—Gaimardia, Astelia, Callixene, Philesia, Drapetes, Bæa, Calceolaria, Pernettya, Oligosporus, Nassavia, Bolax, Azorella, Donatia, Acæna, Hamadryas.

Predominant trees and shrubs.—Fagus antarctica, Salix magellanica, Embothrium coccineum, Pernettya empetrifolia, P. mucronata, Andromeda myrsinites, Baccharis tridentata, Chiliotrichum amelloides, Ribes magellanicum, Escallonia serrata, Fuchsia coccinea, Myrtus nummularia, Berberis ilicifolia, B. inermis, B. microphylla, B. empetrifolia, Drimys Winteri. No cultivation. (Hooker's 'Flora Antarctica' is the best flora of this region.)

23. *Region of Stapeliæ and Mesembryanthema (S.-African or Thunberg's Region).*

Mean temperature, 54°–73° Fahr. (12°–23° C.).

Character.—A succession of mountain ranges and intervening plateaux separate the coast region from the elevated plains in the interior. The coast region has a flora very rich in forms, flowers abundant and beautiful, but the trees or shrubs not luxuriant; no large dense forests, or abundance of climbing plants, &c.; many succulent plants.

Characteristic Orders.—Restiaceæ, Iridaceæ, Proteaceæ, Ericaceæ, Ficoideæ, Bruniaceæ, Diosmeæ, Geraniaceæ, Oxalideæ, Polygalaceæ.

Genera.—Restio, Ixia, Gladiolus, Moræa, Watsonia, Hæmanthus, Strumaria, Agapanthus, Eucomis, Massonia, Strelitzia, Passerina, Gnidia, Protea, Leucadendron, Leucospermum, Serruraria (and many other Proteaceæ), Stilbe, Selago, Stapelia, Erica, Gnaphalium, Helichrysum, Stobæa, Pteronia, Osteospermum, Tarchonanthus, Relhania, Gorteria, Arctotis, Othonna, Stœbe, Œdera, Anthospermum, Mesembryanthemum, Vahlia, Liparia, Borbonia, Lebeckia, Raffnia, Aspalathus, Stavia, Brunia, Phylica, Diosma, Pelargonium, Oxalis, Sparmannia, Muraltia, Polygala, Penæa.

Predominant forms.—On the sandy districts of the coasts: Stapelia, Iridaceæ, Mesembryanthemum, Restio, Diosma. On the mountains: Proteaceæ, Erica, Crassula, &c. On the dry plateaux: Acacia capensis, A. Giraffæ, A. detinens, A. viridiramis, Euphorbia mauritanica, E. tenax, Poa spinosa, Mesembryanthemum, sp., Aloe, Iridaceæ, Erica, Diosmeæ, Restio.

Other remarkable species.—Hæmanthus coccineus, Amaryllis toxicaria, Testudinaria montana, T. elephantipes, Podocarpus elongatus, Salix gariepina, Protea mellifera, P. grandiflora, Leucadendron argenteum, Laurus bullata, Lycium tetandrum, Olea similis, Rhizogum trichotomum, Tarchonanthus camphoratus, Stœbe rhinocerotis, Crassula coccinea, Portulacaria afra, Mesembryanthemum edule, M. turbiniforme, Metrosideros angustifolia, Acacia elephantina, Zizyphus bubalina, Calodendron capense.

Cultivated plants.—The European cereals, fruits, and esculent vegetables; also Sorghum caffrorum, Batatas, Plantains, Tamarind, Guava, Shaddock.

The Kalahari region of Grisebach, which intervenes between this region and the Sudan, is alluded to at p. 687. (The works of Harvey and Sonder afford the best general insight into the nature of this flora.)

24. *Region of the Eucalypti and Epacrides (Australian, or R. Brown's Region.)*

Mean temperature, 53°–73° Fahr. (12°–23° C.).

Character.—The Australian flora, as a whole, is tropical in the north, where it approximates to the Indian monsoon and Oceanic types, in the centre is a dry desert region, while south the climate is like that of the Mediterranean. The vegetation necessarily presents great differences according to the variations in climate. In Tasmania the rainfall is more evenly distributed throughout the year. The Australian is one of the richest and most peculiar floras, but without any considerable profusion

of vegetation. The plants of Swan River present much in common, so far as generic types are concerned, with those of the Cape.

The characteristic Orders and genera are:—Xerotes, Xanthorrhœa, Pterostylis, Casuarinæ, Leptomeria, Pimelea, Proteaceæ (Banksia, Hakea, Persoonia, Grevillea, Petrophila, Isopogon, Dryandra), Myoporineæ, Westringia, Logania, Mitrasacme, Epacridaceæ (Epacris, Leucopogon, Styphelia), Stackhousieæ, Scævoleæ, Goodenovieæ, Stylidiæ, Eucalyptus, Melaleuca, Leptospermum, Acaciæ aphyllæ, Platylobium, Bossiæa, Diosmeæ (Boronia, Zieria), Pittosporeæ, Tremandreæ, Pleurandra, Hibbertia.

Predominant trees and shrubs.—Three fourths of the forests are composed of species of Eucalyptus, the number of which amount to more than a hundred; some are very lofty. Next to these come Proteaceæ, Epacrideæ, Diosmeæ, Casuarinæ, and Acaciæ aphyllæ, forming woods and "bush." Also Coniferæ, Araucaria excelsa, A. Bidwilli, A. Cunninghamii, A. Cookii, Dacrydium Franklinii, Podocarpus spinulosa.

Cultivated plants.—In the European colonies the cereals, fruits, and vegetables of Europe. (For further information consult the works of Robert Brown, Baron von Müller, and specially Bentham's 'Flora Australiensis.')

25. *New-Zealand Region (Foster's Region).*

Temperate climate.

Character.—The flora is more nearly related to that of South Chili than to that of Australia. Evergreen forests, lofty Conifers, and Tree Ferns, Cordylines, &c. abound. Tropical forms vanish, or appear but sparingly. Half the genera European. Approximation to Australia (Pimelea, Myoporum, Epacris, Styphelia, Cassinia, Melaleuca); to South Africa (Gnaphalium, Xeranthemum, Tetragonia, Mesembryanthemum, Oxalis, Restio); to the Antarctic region (Mniarum, Fuchsia, Acæna, Drimys). Many Ferns.

Genera.—Phormium, Pennantia, Knightia, Forstera, Griselinia, Melicope, Dicera, Plagianthus, Melicytus.

Characteristic species.—Cyathea medullaris, Gleichenia furcata, Dracæna indivisa, D. australis, Phormium tenax, Areca sapida, Dacrydium taxifolium, Dammara australis, Podocarpus Totarra, Knightia excelsa, Avicennia resinifera, Andromeda rupestris, Epacris juniperina, Weinmannia racemosa, Tetragonia expansa, Fuchsia excorticata, Melaleuca, sp., Dicera dentata, &c.

Cultivated plants.—Arum esculentum, Convolvulus chrysorhizus, Phormium tenax, &c. In the European colonies the cereals, fruits, and esculents of Central Europe. (Hooker's Flora and Handbook to the Flora of New Zealand constitute the best general works on the Flora of New Zealand.)

Insular Floras.

The flora of islands remote from any continent is of peculiar interest where it has not been interfered with by cultivation or other destructive agency. The questions to be solved are:—How did the plants now existing on these islands get there? Were they created *in situ*, or were they imported? If so, How, when,

and whence? Speaking generally, insular floras comprise some species which are absolutely peculiar or endemic; some which are so closely allied to continental forms, that it may readily be conceived that they came from a common stock at a comparatively recent period; and, thirdly, species identical with those of some continent, and that not necessarily the nearest to them, often indeed, not so; hence the probability that these islets received their vegetation from these distant continents at a geological epoch very remote from the present. Unfortunately cultivation, the destruction of forests, the ravages of goats, rats, and other destructive animals, have in most cases materially altered the character of the flora. The aboriginal flora of St. Helena, for instance, is all but entirely destroyed, and its place supplied by introduced vegetation, or by species in no way peculiar to the island. When near a continent, and divided from it by a shallow sea, the floras of island and continent are, in a broad sense, identical, as those of England and Northern Germany; but where, as in the case of Madagascar, an island is large and separated by a deep channel several hundreds of miles wide, the flora is different. Some islands are of volcanic origin, like Madeira, the Azores, and the Canaries; and the antiquity of their flora can be studied with reference to their geological history.

The Atlantic Islands.

The general character of the flora is distinct, with an intermixture of Mediterranean elements, and of species from the African mainland. Lyell considers that these islands had never any connexion with the mainland, but that they originated as volcanoes in Miocene times, and were peopled by waifs and strays from Europe and Northern Africa in that period. The presence of such North-American types as *Persea* and *Clethra* is explained by the fact that in Miocene times, when the Atlantic volcanoes first reared their crest above the waves, Europe was covered with a very rich vegetation, containing many genera now peculiar to America (Hooker), so that the genera in question in Madeira may be looked on as "survivals" from the Miocene period. *Monizia edulis*, a native of one of the Desertas, belongs to a genus which has no representative elsewhere in the world. This, too, like *Companula Vidalii*, which only exists on one rock off the coast of Flores, may be regarded as a "survival." Hooker (Lecture on Insular Floras, 'Gardeners' Chronicle,' 1867) considers that Volcanic Islands received their flora by means of immigrants from various continents, and does not favour the view that these distant islets ever formed parts of existing continents. The same author points out, in general terms, that islands, owing to the similarity of physical circumstances, are peopled with similar plants, and that their vegetation is consequently similar, as in the abundance of Mosses and Ferns and of evergreen trees. Animals, on the other hand, are rare. Species are few in proportion to genera, genera to Orders, hence the remarkable difference in the flora. The mountains, moreover, have relatively few alpine plants.

The Cape-Verde Islands have a flora which is quite of the Saharan type. St. Helena had a large number of trees of peculiar character showing an African type.

The Mascarene Islands.

Madagascar, Mauritius, Bourbon, and the Seychelles are tropical islands of volcanic or metamorphic origin. Half the species, according to Baker (whose 'Flora of Mauritius' is the most recent enumeration), are peculiar to one or other island, or common to the whole Archipelago, while 6 per cent. are African, 8 Asiatic, 14 common to Asia and Africa, and 21 per cent. common to the Old and New Worlds. The most abundantly represented Orders are Ferns, Orchids, Grasses, Sedges, Rubiaceæ, Euphorbiaceæ, Compositæ, and Leguminosæ. The total proportion of species to a genus is 2–3, and of species to an order between 9 and 10. No less than 269 species, according to Mr. Baker, have been introduced, and have established themselves in Mauritius, while the native flora has been to a large extent exterminated by cultivation, &c.

Pacific Islands, &c.

The floras of the Indian Archipelago, of the Sandwich and Fiji Islands, are closely related to the Indo-Malay type of vegetation, as already mentioned, and form a transition between it and that of Northern Australia. New Caledonia and Lord Howes Island belong to the Australian type as regards their flora, with some peculiar forms. The flora of Norfolk Island, broadly speaking, is allied to the New-Zealand flora, with admixture of Australian and Indo-Malayan types.

The Auckland and Campbell Islands have the general features of New-Zealand vegetation. *Chrysobactron Rossii*, a noble yellow-flowered Asphodel, is one of the characteristic plants.

Antarctic Islands.

Under this head brief mention may be made of Juan Fernandez, the flora of which is mainly South Chilian, with marked preponderance of Composites and many peculiar types.

Kerguelen's Island has a flora allied to that of Fuegia. The Kerguelen Cabbage, *Pringlea antiscorbutica*, is characteristic, and, according to Bennett, differs from most European Crucifers in being wind-fertilized, an interesting fact to be correlated with the large proportionate numbers of wingless insects. The flora of Marion Island is of similar character.

The Falkland Islands are of similar general character to Kerguelen's Land, and are remarkable for being covered with dense tufts of Tussac grass, *Dactylis cæspitosa*, and with hummocks or cushion-shaped masses of an Umbellifer, *Bolax glebaria*.

Cockburn's Island, lat. 64° 12′ S. lat., due south of Cape Horn, yields little or no vegetation beyond Mosses and Lichens of cosmopolitan diffusion.

South-Atlantic Islands.

The floras of St. Helena and Ascension have been already alluded to. It remains to make brief reference to the floras of Amsterdam Island,

St. Paul's, and Tristan d'Acunha. Very little is known of the vegetation of these islets; but a species of *Phylica* is supposed to form the forest of the first-mentioned island, and to connect botanically the islands of St. Helena, Tristan d'Acunha, and Amsterdam one with another and with the African continent, species of *Phylica* being found in each, and most abundantly in South Africa. *Spartina arundinacea*, a grass, is common to the islands of Amsterdam, St. Paul's, and Tristan d'Acunha. *Chenopodium tomentosum*, *Nertera depressa*, *Dactylis cæspitosa*, and *Acæna* indicate a connexion with the Fuegian and Antarctic floras, and through a species of *Pelargonium* with the South-African.

Sect. 4. Statistics of Vegetation.

Number of Species.—Various authors have made computations from existing data, with a view to ascertain the total number of existing species of Phanerogams; but as the opinions of authors as to what limits a species are so extremely varied, it seems useless to occupy space with such speculative matter. The computations range from 100,000 to 300,000 species and upwards. It is somewhat more easy to lay down some general statistical facts regarding the distribution, and particularly in reference to the relative proportions of the more important Classes and Orders, in different regions of the globe.

Relative Proportion of the larger Groups.—Materials are insufficient to enable us to calculate the relative distribution of Cryptogams and Phanerogams in different regions. The former appear to bear a higher proportion to the latter as we recede from the equator to the poles; but this may depend upon our better acquaintance with the Cryptogamic Floras of the northern temperate regions than with the Cryptogams of the warmer climates.

As regards the relative abundance of Monocotyledons and Dicotyledons in different latitudes, it is generally agreed that the proportion of Monocotyledons to Dicotyledons increases from the equator towards the poles—a retrogression of the proportional number taking place, however, in the icy regions of the poles and on the alpine summits. As a rule also, closely connected with the above statements, Monocotyledons are more predominant in proportion to the greater moisture of a climate.

Probably no Orders, except the Leguminosæ and the Compositæ, contain a number of species amounting to 5 per cent. of the total number of Phanerogamic species. Thus the existence of species of one Order in any region exceeding in number 5 per cent. of all species found there, indicates a predominance of that Order. If such predominance occur only in one region, the Order becomes *characteristic* of that region; if such predominance of the same Order occur in many regions, it indicates *wide diffusion* of that Order.

In a very long list of Floras, from all parts of the globe, compared by Alph. De Candolle, it was found that only 35 Orders of Phanerogamia formed more than 5 per cent. in any one or several regions.

The orders which presented in one or but a few floras from 10 to 19 per cent. of the Phanerogamic species were:—

Caryophyllaceæ..	Spitzbergen (14½ per cent.).
Cruciferæ	Spitzbergen (19) and Melville Island (13½).
Leguminosæ	Almost all intertropical and subtropical regions.
Rubiaceæ	Sierra Leone (10).
Proteaceæ	Australia (11½).
Melastomaceæ ..	West coast of tropical America (11¼), Brazil (?).
Saxifragaceæ....	Spitzbergen (14½), Melville Island (15).
Solanaceæ	Ascension (13) (naturalized).
Myrtaceæ	Brazil (?).
Cyperaceæ......	Lapland (13), Iceland (11), Brocken (12).
Orchidaceæ	New Guinea (16½), Java (10), Mauritius (11½), S. Mexico (10).

Of Orders ordinarily exceeding 10 per cent. of a flora,—

Graminaceæ constituted 18 per cent. in Spitzbergen; 21 in Melville Island; 27 in Kerguelen's Land. Compositæ, 18½ per cent in California and Mexico; 19 in the Malouines; 21 in Chili; 22 at Quito; 25 in the S. of Buenos Ayres; 27 in Juan Fernandez.

Orders with more than 30 per cent. occurred in exceptional localities, viz. Compositæ (33⅓) in the elevated parts of Chili, and Cyperaceæ (33⅓) at Tristan d'Acunha.

Certain Orders predominate in particular latitudes, without being in their nature characteristic of those latitudes.

Tropical Floras.—Thus, while in some regions of the tropical zone the Palms, Zingiberaceæ, Marantaceæ, Melastomaceæ, Malpighiaceæ, &c., are really characteristic, the predominant species of the tropical floras are not members of such Orders as Lauraceæ, Menispermaceæ, Anonaceæ, Bombaceæ, which have their maximum in hot climates, but belong to the Leguminosæ, Graminaceæ, and Compositæ, which exceed 10 per cent. generally in the tropics: the Orchidaceæ and Cyperaceæ follow next, then Euphorbiaceæ, Urticaceæ, Melastomaceæ, and Scrophulariaceæ; of which, Melastomaceæ alone belong exclusively to hot regions.

Other Orders occurring in many tropical floras, but forming less than 5 per cent. of the species, are:—

Convolvulaceæ, Malvaceæ, Piperaceæ, Zingiberaceæ, and Marantaceæ, Solanaceæ, and less commonly Acanthaceæ, Amentaceæ, Apocynaceæ, Bignoniaceæ, Boraginaceæ, Capparidaceæ, Cucurbitaceæ, Gentianaceæ, Labiatæ, Lauraceæ, Loranthaceæ, Malpighiaceæ, Myrtaceæ, Umbelliferæ, Palmaceæ, Passifloraceæ, Rosaceæ, Rutaceæ, Anacardiaceæ, and Verbenaceæ.

The Ferns are likewise exceedingly predominant in species in the islands of the tropics (16, 21, 26 per cent.).

Temperate Floras.—In northern temperate latitudes (from the tropic to 60° N. lat.), again, Compositæ, Graminaceæ, Cyperaceæ, and Leguminosæ predominate in species—the Cyperaceæ increasing northward, the Leguminosæ rapidly decreasing (Granada 8 per cent., Yorkshire 4½ per cent.). Next follow Cruciferæ, Umbelliferæ, and Caryophyllaceæ; then Labiatæ, Rosaceæ, and Scrophulariaceæ. No other Orders exceed 5 per cent. of the species, and only attain this in exceptional localities.

In the northern zone beyond 60° N. lat., the species predominating northwards are Graminaceæ, Cruciferæ, Saxifragaceæ, Caryophyllaceæ, Ranunculaceæ, Rosaceæ, Cyperaceæ (5–7 per cent.). Compositæ form 7 per cent. in Melville Island, but only 4–5 per cent. in Spitzbergen. Amentiferæ (Betulaceæ, Salicaceæ, &c.) and Juncaceæ barely reach 5 per cent.; Polygonaceæ, Ericaceæ, and Scrophulariaceæ approach this number, but are mostly below it.

In the south temperate zone we find two classes of regions, one dry, the other with a damp climate. The former comprehends the Cape of Good Hope, Australia, Chili, and La Plata. Compositæ predominate at the Cape and in America, but in Australia fall to 7 per cent. Leguminosæ, on the contrary, make but 7 to 12 per cent. in America and at the Cape, but 14 per cent. in Australia. The Grasses are not more than 3 to 6 per cent. anywhere, and the Cyperaceæ still fewer.

The Cape and Australia have, however, certain especially abundant Orders; thus Proteaceæ form 2 to 6 per cent. at the Cape, 8–12 per cent. in Australia; Myrtaceæ 9 per cent. and Epacridaceæ 4–5 per cent. in Australia; Iridaceæ 4–6 per cent., Liliaceæ 4–5 per cent., and Ericaceæ 2–6 per cent. at the Cape; Stylidiaceæ and Goodeniaceæ are especially Australian.

In the moist regions, comprising parts of the African coast, Tasmania, New Zealand, Island of Chiloe, &c., the Grasses and Compositæ increase in departing from the tropics; Cyperaceæ rise to 4–8 per cent.; Orchidaceæ, 4½–8½ per cent.; and Ferns are very numerous in the islands. Restiaceæ increase in Tasmania, but Proteaceæ, Leguminoseæ, with Stylidiaceæ, Goodeniaceæ, &c. decrease. The proportions in the Southern extremity of America approach those of the temperate and moist regions of the northern hemisphere.

As a general statement, it may be said that of the three most frequently predominating Orders, Leguminosæ are diminished in proportion to temperature, the Compositæ are lessened by combined cold and humidity, and the Graminaceæ are least predominant where the climate is dry.

It must be borne in mind that the above calculations are approximate only, and apply to species, or genera, or orders, and by no means represent the distribution of *individual* plants.

CHAPTER III.

BOTANICAL GEOLOGY.

Sect. 1. Nature and Importance of Fossil Plants.

Remains and traces of plants are met with in most of the stratified rocks which have been produced by successive geological changes of the earth's surface. These remains afford an indication, more or less perfect in different cases, of the nature of the

vegetation which has existed in earlier periods of the world's history. Vegetable remains found imbedded in geological formations are called *fossil plants*; and the condition in which these fossils occur are exceedingly varied, both as to the nature of the substance preserving the vegetable forms, and the degree of perfection of the forms preserved.

The principal kinds of fossils may be classed as follows:—1. *Petrified plants*, in which the structures of plants have been more or less completely impregnated with mineral matter, hardening them into a stony mass. They present various modifications, in which more or less of the organic matter remains, completely impregnated with mineral substances, or where the mineralization is so complete that the organic substance has totally disappeared. The mineral substance of such fossils is different in different cases. Silicified remains are the most common; fossils impregnated with carbonate or sulphate of lime abound in other strata, while fossils of dense or earthy ironstone, argillaceous ironstone, and, lastly, iron-pyrites are frequent in particular rocks; impregnations with rock-salt, oxide of copper, alumina, &c. are rarer.

2. *Coal*, where the vegetable substance is more or less completely converted into a solid, black, combustible carbonaceous substance, of stone-like aspect. This occurs in almost every possible modification, in masses or in the form of isolated plants or organs of plants, from the solid stony *anthracite* to the *brown coal* or *lignite*, which preserves the organic texture and is recognizable at first sight as vegetable matter. Coal-beds are formed through the accumulation of vast masses of vegetation, and their conversion through pressure and chemical changes into solid masses; but leaves, stems, or parts of stems, such as layers of bark, fruits, &c., converted into coal, are found isolated in strata of various composition. With these last are intimately connected the numerous fossils which are true petrifactions, but have the organic matter preserved in the mineral substance in the condition of coal, giving a coal-like aspect to the fossil.

3. *Impressions* or *natural casts* of plants or organs of plants, which have been formed by the vegetable objects being incrusted by, or imbedded in, mineral substance and decaying subsequently to the solidification of the enclosing substance; the cavity left by the decayed vegetable may be filled up by the same or a different mineral substance; and casts of the internal parts of stems &c. are met with, from the penetration of the mineral matter into cavities formed by the quicker decay of succulent structures, such as pith.

4. *Objects contained in Amber*, the fossil resin of a Pine, which has accidentally enclosed various vegetable and animal bodies which it flowed over while liquid. The objects are sometimes thoroughly impregnated with amber, like microscopic objects enclosed in Canada balsam, these having been enclosed in a dead or dry condition; in other cases, where fresh organs have been enclosed, hollow casts only are found, the enclosed matter having been more or less decomposed.

The study of vegetable fossils is far less satisfactory than that of animal remains, since, in the great majority of cases, the structures most distinctive of the subordinate groups of plants are formed of very perishable matter. Genera, and even species, of animals may be recognized by bones

and shells, which are of a very persistent nature, and are found abundantly in stratified rocks. The preservation of fossils can only have occurred through the agency of water, impregnated with mineralizing matter, or loaded with mud which enclosed the remains: the vegetable bodies which can resist the long-continued action of water are few; and these mostly afford only characters of large sections of the vegetable kingdom, without furnishing generic, far less specific distinctions. Added to the fragmentary character of the fossils known, those kinds hitherto found possibly only represent partially prevailing forms of vegetation.

Attempts, however, have been made, by combining the conclusions of stratigraphical geology and animal palæontology with those of vegetable palæontology, to form conceptions of the character of the vegetation of succeeding geological periods. The ideas obtained in this way, however, are very superficial and exceedingly speculative. Still there is much that is promising in the investigations; and the general tendency of all the facts hitherto collected is to indicate that there has been a gradually increasing complexity of organization in the plants successively created, that the plants of the earliest epochs belong to the lower Classes, and that the higher Phanerogams appeared only in the later formations—in the last of these probably in smaller proportion than in existing vegetation. In the earliest formations (Cambrian, Silurian, &c.) the few vegetable remains are those of Algæ, Fucoids, &c. In the Devonian and Carboniferous periods vascular Cryptogams, Ferns, Lycopods, Equiseta prevailed. In the Triassic and Oolitic periods Gymnospermous plants formed a marked feature, such as Conifers, Cycads, &c., with Tree-ferns and traces of Monocotyledonous plants. With the Cretaceous period appear Angiospermous plants, beginning with a preponderance of Incompletæ, and passing through Dialypetalæ to the more recent formations, where Gamopetalous plants prevail. But in all cases, though there is evidence of progress, there is an overlapping of the characteristics of one period by those of another.

One important point, however, must not be overlooked in inquiries relating to this subject; that is, the probability of the coexistence of diversified *local floras*, as at the present day, the remains of which might, from purely systematic considerations, be regarded as of different antiquity.

In illustration of this, it may be observed that the remains found in the European formations belonging to the epoch immediately preceding the present offer a general resemblance to the prevailing forms of existing North-American vegetation.

Sect. 2. Fossil Plants characterizing particular Geological Formations.

1. *Flora of the Palæozoic Strata.*

Lower and Middle Palæozoic, or Transition Period.—Comparatively few plants are known in these strata, and a considerable amount of uncertainty exists in reference to the determination of the fossils. What remnants remain in the Cambrian, Silurian, and Lower Devonian series are apparently those of marine Algæ. In the more recent deposits of this age Ferns, including some allied to *Hymenophyllum* and *Trichomanes*,

Calamites, Asterophyllites, and Conifers are found. *Psilophytum* extends in America through Upper Silurian and Devonian formations. It is a plant probably Cryptogamous, but not referable to any existing form, but presenting resemblances to Rhizocarpeæ and Lycopodiaceæ. *Cyclostigma* is more distinctly Lycopodiaceous, as also *Lycopodites*. Conifers are represented by *Prototaxites*, described as presenting indications of Coniferous structure in a simpler condition than now existing. In the Upper Silurian traces of Lycopods occur.

Upper Palæozoic, or Carboniferous System.—The known floras of this system, remarkable for the presence of the great Coal-beds of Europe, afford a very large number of species, in which there is a continued great predominance of the Leafy Cryptogamia (Ferns, Lycopods, Equiseta, &c.), in many respects of higher organization than those now existing.

The principal characteristics revealed here are the absence of Dicotyledons, the paucity of Monocotyledons, the predominance of the Ferns and allied Classes, and of certain plants of organization not met with in existing vegetation, referred by some authors to the Class of Gymnosperms, by others, and probably more correctly, to the vicinity of Lycopodiaceæ, &c. Conifers and Cycads begin to appear, with Stigmarias, Sigillarias, *Lepidodendron*, &c. The general character of this flora is very monotonous, and alike in character from the poles to the equator.

About 150 species of Ferns have been found in the British Coal-formation. *Lepidodendron* has the habit and spores of *Lycopodium*. *Lepidostrobus* is the fruit-spike of *Lepidodendron*, having the structure of existing *Lycopodium*. *Calamites* seem to have been gigantic Equiseta. *Asterophyllites*, *Annularia*, *Sphenophyllum* are possibly forms of Calamites. *Stigmaria* is the root of *Sigillaria*, a plant of doubtful affinity, referred by Carruthers to Lycopodiaceæ, by others to Gymnosperms. The Conifers are represented by *Dadoxylon*, allied to *Araucaria*, *Sternbergia*, *Trigonocarpum*, &c. *Sternbergia* is supposed to have been the pith of *Dadoxylon*. *Antholites* has much the general appearance of an *Orobanche*.

Permian System.—The fossils of the Magnesian Limestone afford only fragmentary representatives of the Carboniferous flora, most of the characteristic genera having disappeared. The Orders are much the same, but less numerously represented by species. Silicified Coniferous wood, *Walchia*, Ferns, Calamites, *Lepidodendron*, and Algæ are found, and also evidence of the existence of Palms. *Nœggerathia* has the venation of *Salisburia*.

2. *Flora of the Mesozoic, or Secondary Strata.*

Triassic, or New Red System.—In the "Variegated Sandstone" strata of this formation, comparatively few species have yet been observed. The Carboniferous species have disappeared; Ferns still predominate and exhibit peculiar forms; Conifers (*Voltzia*, *Haidingera*) are abundant; Cycadeæ rare, and a few doubtful Monocotyledons (*Yuccites*, *Palæoxyris*) occur. In the "Keuper" Sandstones, with a general analogy in the proportion of Orders, except that Coniferæ are rare and Cycadaceæ abundant, the genera of Ferns and allied Orders are mostly distinct from those of the Vosgesian, or "Variegated" Sandstones.

Liassic System.—The essential characters of this epoch are the great

predominance of Cycadeæ (*Zamites*), which here appear in several new genera, and the existence of Ferns with more highly organized foliage than that of the genera of older formations. Algæ, Fungi, Lichens, Lycopods, and Conifers also existed at this period, but no Angiospermous Dicotyledons have yet been discovered.

Oolitic System.—The nature of the strata referable here is very diverse; the general character of the fossil vegetation consists in abundance of Ferns proper, Equiseta, and of Cycadeæ, especially of those genera (*Zamites* and *Otozamites*) *approaching nearest to existing forms, and the greater frequency of the Coniferæ, Brachyphyllum* and *Thuytes, than in* the Lias. Cones of Araucarias have been found, as well as endogenous plants allied to *Pandanus* and *Arum*. Algæ, Marsileas, Lycopods are also found. There are a large number of known species. The dirt-beds of Portland are layers of soil with remains of Cycadaceous trees in an erect position. Some of these are distorted by pressure into the shape of birds' nests.

Wealden System.—This formation, remarkable as a freshwater product, has afforded comparatively few species of plants, mostly congeneric, although specifically distinct from those of the Lias; but the proportion of the Cycadaceæ to the Ferns is smaller. *Equisetum* and *Chara* (the latter by its fruits) are represented. Dicotyledons have not been discovered.

Cretaceous System.—In this formation we are at once struck with the diminution of Ferns, Equisetaceæ, and allied forms, the reduction of the species of Gymnosperms, and the appearance of Angiospermous Phanerogamia, chiefly dicotyledonous (*Betula, Myrica, Salix*, &c.), though traces of Palms and Grasses have been met with. The Cycadaceæ are still numerous; but they and the Coniferæ do not more than equal the Dicotyledons. The genus *Crednaria*, supposed to belong to the last class, is very characteristic of the Chalk formation. The Ferns and Equisetaceæ almost disappear.

The fossil plants of the Upper Cretaceous system, the equivalent of the Upper Chalk of this country, show a terrestrial flora in which all the great subdivisions of the vegetable kingdom are represented. Dr. Debey estimates the number of species at Aix at about 200, of which 67 are Cryptogams. *Gleichenia, Lygodium*, and *Asplenium* among Ferns have been identified as generically identical with the plants now so named. Among Conifers, *Cycadopteris* closely resembles *Sequoia*; *Araucarias* also are found, but few Cycads. Pandanads existed, and, among Dicotyledons, Figs, Oaks, Walnuts, Myrtles, and numerous Proteads, the structure of the leaves of the latter being so perfectly preserved that even the stomata may be seen. Attempts have been made even to correlate the genera with existing types of Proteads; but this is a very hazardous procedure, seeing how variable the leaves of Proteaceæ are. Still the general indications point to a vegetation like that of Australia.

3. *Floras of the Tertiary System.*

The floras of this system form a more or less connected whole, which is continued in the later strata into existing vegetation. They are especially distinguished from those of older epochs by

the abundance of Angiospermous Phanerogams, Dicotyledons, and Monocotyledons—above all, Palmaceæ. But a sort of transition takes place from the Cretaceous period to the Eocene. In this system, however, the proportion of Gymnosperms rapidly decreases, and the Cycadaceæ disappear from Europe, while the Conifers approach the character of the existing genera of temperate regions.

Eocene Flora.—The distinctive characteristics, as compared with other epochs, are the presence, though rare, of Palmaceæ, *Nipadites*, the comparative abundance of Algæ and marine Monocotyledons (*Caulinites*, *Zosterites*, &c.), and the existence in Europe of numerous now exotic forms, such as *Gleichenia* among Ferns, especially represented by the fossil fruits of the Isle of Sheppey, the Barton Bed in the Isle of Wight, &c. Though less rich than the Miocene, these formations include a large number of species of an Australian or Indian type, such as Lauraceæ, *Aralia*, *Anona*, *Ficus*, various Proteaceæ, *Petrophila*, *Is pogon*. Temperate species, such as are found in the Miocene, are wanting.

Miocene Flora.—A very rich flora. No less than 900 species have been detected in one locality in Switzerland by Heer. The Australo-Indian forms give place to plants of an American type, resembling the existing vegetation of the United States, Mexico, and Japan. One of the most striking features is the abundance of Palmaceæ, *Sabal*, together with Gamopetalous Dicotyledons, especially a supposed Rubiaceous genus, *Steinhauria*. The list of fossils contains also a *Bambusa*, Lauraceæ, Combretaceæ, Leguminosæ, Apocynaceæ, *Vitis*, belonging to warm climates, with many Amentaceous trees, *Populus mutabilis*, *Carpinus*, Aceraceæ, Proteaceæ, Nymphæaceæ, and other plants now belonging to temperate regions. Numerous vegetable remains occur in beds of this formation at Bovey Tracey, Devonshire, and in the Isle of Wight. At Bovey Tracey one bed is described as a perfect mat of the débris of a *Sequoia* intermediate between the existing Red-wood, *S. sempervirens*, and *S. gigantea* (*Wellingtonia*) of California. At Œningen, on the Rhine, are beds of this formation containing numerous insects and plants, the latter being of special interest in this case, because the leaves are so often associated with fruits, rendering the identification so much more trustworthy. Numerous Maples with foliage and samaræ have been found. Planes also are found with leaves and fruit, and with the bark peeling off, as in existing species.

The flora of the Miocene period, as a whole, is of a subtropical and temperate character, and presents many American forms, such as *Liquidambar*, *Sequoia*, &c. In the Arctic regions, Greenland, &c., Miocene beds occur, very rich in vegetable remains, many of which are pronounced identical with those of the Miocene beds of Central Europe. In these now inhospitable regions once grew at least ten species of Conifers, in-

cluding Sequoias, *Taxodium distichum*, *Abies excelsa*, Common Spruce, Salisburias, Oaks, Planes, Poplars, Elms, Birch, Maples, Walnuts, Magnolias, *Andromeda*, *Viburnum*, *Zamia*, Vines, Ivies, Ferns, and many others, more or less correctly referred to existing generic types, but, in any case, affording evidence of a subtropical or warm temperate climate. It is conceivable, then, that the plants of the Miocene epoch, so many of which are of American types, started from Greenland and were dispersed throughout Europe, Asia, and America. Unger and Heer supposed that the plants might have migrated from America to Europe by way of a now sunken continent, the Atlantis of Plato, the position of which is marked by the accumulations of Sargasso Weed. The presence of American genera, *Clethra* &c. in Madeira, has already been alluded to with reference to this view. Asa Gray and Oliver, however, consider that the existing evidence is more favourable to a migration from America through Asia to Europe!

Pleiocene Flora.—The Dicotyledons predominate, and are most varied, as in existing vegetation; the Monocotyledons are rare; and the Palmaceæ of the preceding epochs are wanting. The general analogy of the flora is with those of the temperate and warmer regions of Europe, North America, and Japan at the present day. According to the determinations made by palæontologists, many existing genera are represented, such as *Glyptostrobus*, *Taxodium*, *Salisburia*, Cyperaceæ, *Comptonia*, Thymelaceæ, Santalaceæ, Lauraceæ, *Liquidambar*, *Nyssa*, *Robinia*, *Gleditschia*, *Bauhinia*, *Cassia*, *Acacia*, *Rhus*, *Juglans*, *Ceanothus*, *Celastrus*, *Sapindus*, *Liriodendron*, *Capparis*, *Sideroxylon*, *Achras*, *Symplocos*, Cornaceæ, Myrtaceæ, Pomaceæ, Tiliaceæ, Magnoliaceæ, &c. This list includes especially modern North-American genera, which existed at that time in Europe. *Quercus*, *Acer*, &c. appeared then as now.

Pleistocene Deposits.—The glacial drift and the diluvial deposits belonging to this group afford hardly any recognizable vegetable remains, beyond fragments of fossil wood of Coniferæ, met with occasionally in connexion with the bones of extinct Mammalia and in a few Lignite beds.

The flora of the Glacial period still exists in Alpine districts.

4. *Floras of Early Formations of the present Geological Period.*

The formations referable to this group consist chiefly of freshwater calcareous deposits (tufa), the older peat-bogs, and forests now buried or submerged beneath the sea.

The remains existing in calcareous tufa have not yet been well investigated, partly because the beds are not greatly developed in most countries, and partly because they usually contain only casts of vegetable structure, produced through incrustation. As far as we know, the plants are similar to those of the existing floras of the regions, with a few exceptions.

The old peat-bogs, especially of Northern Europe, often contain vast quantities of recognizable vegetable remains, belonging to species no longer growing in the same spots, but found further south, as remains of *Corylus*, *Pinus picea*, &c. in the Shetland Islands, of Oaks, Maples, Limes, Ash, &c. in Sweden, beyond the present limits of those plants.

Remains of forests formed of still existing species occur in many parts of Europe, enclosed in diluvial beds. The city of Breslau stands on the site of an ancient forest, whence the trunks of *Quercus pedunculata* are dug out; the same is the case with the city of Bamberg, where the trunks of trees of great diameter have been found in excavations for railways, &c. Similar trunks of Oak are occasionally dug out of the diluvial beds in England, as in the upper part of the valley of the Medway.

Submarine forests are known to exist off many points of the British coast and the west coast of France; wood obtained from a large submerged bed off the coast of Pembrokeshire is found to consist of Oak and Alder, and of *Pinus sylvestris*: the Oak, Elm, Hazel, Walnut, &c. are found in the British Channel. In the Lake-dwellings of Switzerland seeds of Cereals, Apples, Nuts, &c., and Linseed have been found, indicating not only the existence of these plants, but also, as in the case of Cereals, of cultivation.

These facts, together with the analogous but more complete evidence derived from animal remains, show a gradual transition from the Tertiary to the present geological epoch.

As to the wider question of the descent of existing species from their fossil representatives, or from preexisting forms now extinct, such filiation can hardly be doubted in many cases, although the exact line of descent is often not traceable. On the other hand, many of the earlier types of vegetation were of their kind more highly organized than their existing representatives; hence it is a question whether the latter are really degenerate descendants from their progenitors, or whether the more highly endowed Lycopods and Equiseta, for instance, have not died out and become extinct. Thallophytes seem to have existed in all ages much as we see them now. Vascular Cryptogams and Conifers early came into existence, and were, as we have seen, highly organized. Traces of Angiospermous Dicotyledons are not visible till a much more recent, but still inconceivably remote period; while from the time of the Eocene and Miocene periods there is a gradual increase in the number of forms, such as are now found in various parts of the globe.

It is clear, then, on the whole, that there has been a succession of vegetable types, and a gradual progression in morphological complexity, but that such succession has been interrupted and not continuous in any one locality, that many links have been utterly lost, and many forms become extinct, so that the attempts made to create a "phylogeny" or genealogical history of the Vegetable Kingdom on so imperfect a basis as is now available must be accepted with great reserve.

INDEX TO SYSTEMATIC BOTANY,

CONTAINING THE

BOTANICAL NAMES OF CLASSES, ORDERS, AND GENERA, AND THE VERNACULAR NAMES OF SPECIES REFERRED TO IN PART II. OF THIS WORK.

GENERAL AND GLOSSARIAL INDEX.

[The explanations of the technical terms are given at the pages referred to.]

THE END.

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